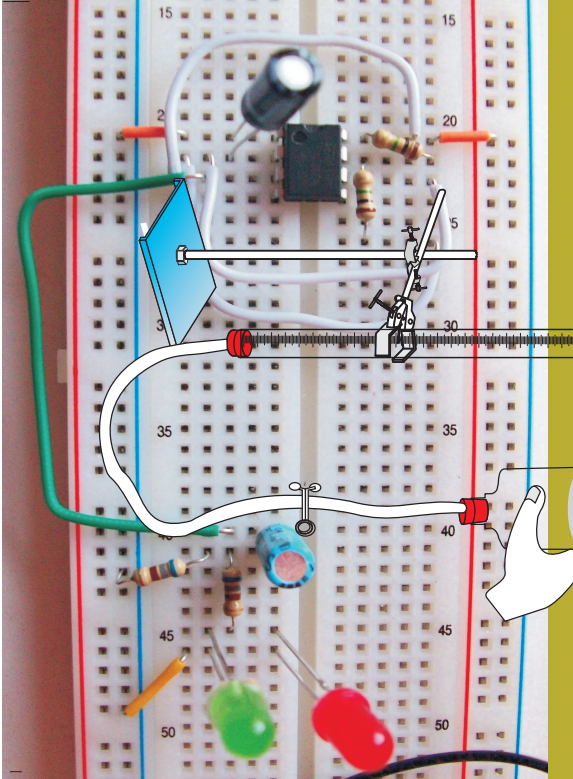
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स्वच्छ भारत

एक कदम स्वच्छता की ओर

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Manual of Higher Secondary
Physics Laboratory Kit

For Classes XI and XII

विद्यया ऽमृतमश्नुते
एन सी ई आर टी
NCERT
राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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Preface

The National Council of Educational Research and Training (NCERT) has already developed Science and Mathematics Kits for upper primary and secondary stages and Micro Scale Chemistry Kit for higher secondary stage in its endeavour to support teaching and learning in schools by inculcating process skills of science. These kits have been well received in States and schools. Over the years, need has been expressed by different stakeholders in schools for a kit at the higher secondary stage in physics. Improvising the apparatuses used in traditional physics laboratories and developing low cost items which can fit in a portable box was indeed a challenging task. But with dedicated and sustained effort of the Division, we have finally succeeded in designing and developing such a kit.

This kit is primarily meant for schools where either a functional laboratory does not exist or a lab does not have proper instruments. Most of the experiments and activities prescribed in the NCERT syllabus of Physics for higher secondary classes can be performed by using this kit. Work is in progress for improvising some more items like Searle's apparatus and Travelling microscope and we hope that soon these items will also find place in the physics laboratory kit. Even in absence of these items, a student can perform the required number of experiments, given the option available in the list of prescribed experiments.

This kit will facilitate practical work in our rural schools also which usually lack proper physics laboratory and necessary equipments. Experiments are the key component of any science curriculum, but in practice it has been observed that most of our rural schools and even some urban schools are not properly equipped with the laboratory facilities required at higher secondary stage. This endeavour may give a plausible solution to this basic problem and can encourage teachers and students to do science in a manner it is expected.

We hope that design of some of the items of this kit will inspire teachers and students to think of alternative design/methods for performing a particular experiment by using local resources. In addition to the experiments given in the list, many more experiments can be carried out using the same kit items.

The advantage of this kit is that it is portable and therefore it can be carried into the classrooms and can also be used for demonstration purposes.

In this kit we have modified/improvised/customised many of the instruments required in performing experiments at higher secondary stage.

Some of the examples are:

- Improvised optical bench—In traditional labs optical benches are bulky and costly, but we have improvised optical bench which is small in size and light in weight so that it can be moved easily from one place to other.
- Improvised meter bridge—Total length of this device, traditionally, is more than one metre, therefore we have made it in two halves that can be joined with the help of a jointer.
- Small size potentiometer—Normally the length of this device is also more than one metre, but we have improvised it by designing it on approximately half metre board.

- Improvised apparatus for verification of Boyle's law—In place of costly and sophisticated apparatus used in traditional lab for this purpose we have improvised it with the help of simple syringe and wooden blocks.
- Improvised apparatus for resonance of sound—We have used a tube which can also be used in another experiment for finding coefficient of viscosity of liquids, and in this way reduce the cost and space.
- Diode and transistor characteristic apparatus—Traditional laboratories use costly setup for semiconductor experiments but we have developed low cost power supplies fitted in a box and provided with a breadboard .With the help of these not only the experiments mentioned in the manual but also many other experiments can be performed.

We have improvised many other items like sonometer, resistance box, pan balance, etc.

No attempt has been made to improvise some of the items like vernier callipers, screw gauge, and spherometer. Because firstly we don't want to compromise with precision of the measurements made by these devices and secondly, these items are neither bulky nor costly and are easily available in school labs.

This manual consists of two parts—The first part covers the experiments and activities for Class–XI and the second part the experiments and activities for Class-XII. Most of the experiments have been presented under the following subheadings — Aim, Apparatus and Material Required, Description of Apparatus, Formula Used, Procedure, Observations and Calculation, Result, Precautions and Sources of Error.

We have adopted/adapted some part of Laboratory Manual in Physics for Classes XI–XII developed by NCERT during 2010. We acknowledge the contribution of members of development team of the manual in Physics.

Each of the experiments and activities suggested in this kit has gone through a series of try-outs, modification before finalisation. We are grateful to the teachers and subject experts from different institutions who participated in the workshops organised for the development, review and refinement of the kit items and kit manual.

I acknowledge the valuable contributions of V.P. Srivastava, former *Professor* of Physics and other team members who contributed and helped in the development of the higher secondary Physics Kit and Kit Manual. Special thanks are due to Ashish Kumar Srivastava, Coordinator of this programme for his dedicated and valuable contribution in the development of this kit and kit manual.

We warmly welcome comments and suggestions from our valued users for further improvement of this Kit and Kit Manual.

R.K. Parashar
Professor and *Head*
Division of Educational Kits

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The Council also acknowledges the development team of Laboratory Manual Physics, for Class XI and Class XII. Special thanks are due to V.B. Patil, *Technical Officer* for providing the technical support during development of the Kit.

The Council also acknowledges the support and facilities provided by DEK and its Staff; Satish Sharma, Anil Nayal Draftsman. The efforts of *Junior Project Fellows* Nivedita, Richa Tripathi, Faheem Akhtar, and *DTP Operator* Nargis is also acknowledged.

The efforts of Publication Division, NCERT, Ilma Nasir (*Editorial Assistant-Contractual*) and Aarti (*DTP Operator-Contractual*) in bringing out this publication are also appreciated.

Contents

Preface *iii*
List of Higher Secondary Physics Laboratory Kit Items *xi*

Experiments for Class XI

E1 Use of Vernier Callipers to: **1**
(i) measure diameter of a small spherical/cylindrical body.
(ii) measure the dimensions of a given regular rectangular solid body of known mass and to calculate its volume and density.
(iii) measure the internal diameter and depth of a given hollow cylindrical object like beaker/tumbler/calorimeter and to calculate its volume.

E2 Use of screw gauge to: **7**
(i) measure diameter of a given wire,
(ii) measure thickness of a given sheet; and
(iii) determine volume of an irregular lamina.

E3 To determine the radius of curvature of a given spherical surface by a spherometer. **12**

E4 To determine mass of two different objects using a beam balance. **16**

E5 Measurement of the weight of a given body (a wooden block) using the parallelogram law of vector addition. **19**

E6 Plot L – T and L – T^2 graphs for a simple pendulum and to find the effective length of second's pendulum using appropriate graph. **23**

E7 To study the relation between force of limiting friction and normal reaction and to find the coefficient of friction between surface of a moving block and that of a horizontal surface. **27**

E8 To find the downward force due to gravity acting on a roller along an inclined plane, and to study its relationship with the angle of inclination 'θ' by plotting graph between force and sin θ. **31**

E9 To find the force constant and effective mass of a helical spring by plotting T^2 - m graph using method of oscillation. **33**

E10 To study the variation of volume (V) with pressure (P) for a sample of air at constant temperature by plotting graphs between P and V and that between P and $\frac{1}{V}$. **37**

E11 To determine the coefficient of viscosity of a given liquid by measuring the terminal velocity of a spherical body. **41**

E12 To study the relationship between the temperature of a hot body and time by plotting a cooling curve. **45**

E13 (i) To study the relation between frequency and length of a given wire under constant tension using a sonometer. **48**

(ii) To study the relation between the length of a given wire and tension for constant frequency using a sonometer.

E14 To determine the speed of sound in air at room temperature using a resonance tube. **52**

E15 To determine the specific heat capacity of a given (i) solid and (ii) liquid by the method of mixtures. **56**

Activities

A1 To make a paper scale of given least count: (i) 0.2 cm and (ii) 0.5 cm, and to use these scales to measure length of a given object. **62**

A2 To determine the mass of a given body using a metre scale by the principle of moments. **64**

A3 To plot a graph for a given set of data choosing proper scale and show error bars due to the precision of the instruments. **67**

A4 To measure the force of limiting rolling friction for a roller (wooden block) on a horizontal plane. **70**

A5 To study the variation in the range of a jet of water with the change in the angle of projection. **73**

A6 To study the conservation of energy of a ball rolling down an inclined plane (using a curved channel or a transparent flexible tube). **76**

A7 To study dissipation of energy of a simple pendulum with time. **79**

A8 To observe the change of state and plot a cooling curve for molten wax. **82**

A9 To observe and explain the effect of heating on a bi-metallic strip. **84**

A10 To study the effect of heating on the level of a liquid in a container and to interpret the observations. **86**

A11 To study the effect of detergent on surface tension of water by observing capillary rise. **88**

A12 To study the effect of load on depression of a suitably clamped metre scale loaded; **90**

(i) at its end

(ii) in the middle.

Prelims Pages.indd 8 04-01-2019 10:14:17

Experiments for Class XII

E1 To determine resistance per unit length of a given wire by plotting a graph of potential difference versus current. **94**

E2 To determine the resistance of a given wire using a metre bridge and hence determine the resistivity of the material of the wire. **97**

E3 To verify the laws of combination of resistances (series and parallel) using a metre bridge. **103**

E4 To compare the emf of two given primary cells (Daniel and Leclanche cells) using a potentiometer. **107**

E5 To determine the internal resistance of a given primary cell using a potentiometer. **111**

E6 To determine the resistance of a galvanometer by half-deflection method and to find its figure of merit. **114**

E7 To convert the given galvanometer (of known resistance and figure of merit) into (i) an ammeter of a desired range (say 0 to 30 mA) and (ii) a voltmeter of desired range (say 0 to 3 V) and to verify the same. **119**

E8 To determine the frequency of alternating current using a sonometer. **125**

E9 To find image distance (v) for different values of object distance (u) for a given concave mirror and to calculate its focal length. **129**

E10 To find the focal length of a convex lens by plotting graphs between u and v or between $1/u$ and $1/v$. **133**

E11 To find the focal length of a convex mirror using a convex lens. **138**

E12 To find the focal length of a concave lens with the help of a convex lens. **141**

E13 To determine the angle of minimum deviation for a given glass prism by plotting a graph between the angle of incidence and the angle of deviation. **145**

E14 To determine the refractive index of a liquid (water) using **149**
(i) concave mirror,
(ii) convex lens and a plane mirror.

E15 To draw the I-V characteristic curves of a p-n junction in forward bias and reverse bias. **156**

E16 To draw the characteristic curve of a Zener diode and to determine its reverse breakdown voltage. **159**

E17 To study the characteristics of a common emitter npn(or pnp) transistor and to find out the values of current and voltage gains. **161**

Activities

A1 To assemble the components of a given electrical circuit. **165**

A2 To draw the diagram of given open circuit comprising atleast a cell/battery, resistor/rheostat, key, ammeter and voltmeter. Mark the components that are not connected in proper order. Correct the circuit and also draw the corrected circuit diagram. **167**

A3 To measure the resistance and impedance of an inductor with or without iron core. **169**

A4 To measure resistance, voltage (dc/ac), current (dc) and check continuity of a given circuit using a multimeter. **174**

A5 To assemble a household circuit comprising three bulbs, a rocket three (On/Off) switches, a fuse and a power source (3V A.C. source). **176**

A6 To study the variation in potential drop with length (potential gradient) of a wire for a steady current. **177**

A7 To study the effect of intensity of light (by varying distance of the source) on a LDR (Light Dependent Resistor). **180**

A8 To identify a diode, a LED, a transistor, an IC, a resistor and a capacitor from a mixed collection of such items. **182**

A9 (i) Check whether the diode is in working order. **185**
(ii) Distinguish between npn and pnp transistor.
(iii) Identify base, emitter, and collector of a transistor.

A10 To observe refraction and lateral deviation of a beam of light incident obliquely on a glass slab. **187**

A11 To observe polarisation of light using two polaroids. **189**

A12 To observe diffraction of light due to a thin slit. **190**

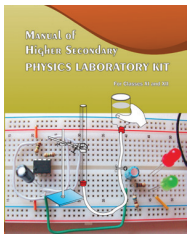
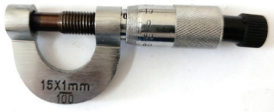
A13 To study the nature and size of the image formed by **191**
(i) a convex lens
(ii) a concave mirror on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror).

A14 To determine the focal length of two lenses in contact. **195**

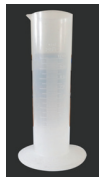
Appendix-1 Optical bench assembling **197**

Prelims Pages.indd 10 04-01-2019 10:14:17

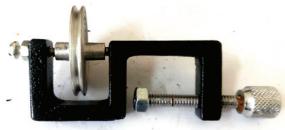
List of Higher Secondary Physics Laboratory Kit Items

S.No.	Item Name	Figure/Setup	Uses
1.	Kit manual		For assembling experimental set-ups and performing experiments and activities.
2.	Kit box with carton		For keeping kit items.
3.	Vernier caliper		For measuring internal dimensions, external dimensions and depth.
4.	Screw gauge		For measuring thickness of a sheet or diameter of a thin wire.
5.	Spherometer		For measuring radius of spherical surfaces.

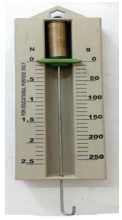
Prelims Pages.indd 11 04-01-2019 10:14:18

6.	Beam balance		To measure the mass of objects in different experiments.
7.	Laboratory stand assembly (a) M.S. rod (b) Boss head- (2 each) (c) G clamp (d) Clamp- (2 types) (e) Base plate		To hold resonance tube, boiling tube, capillary tube, simple pendulum, bimetallic strip etc., used in various experiments.
8.	Measuring cylinder		To measure volume of liquids.
9.	Stopwatch with split timeout		To measure short intervals of time.
10.	Inclined plane		To establish relationship between downward force and angle of inclination.
11.	Steel roller		To use in inclined plane set-up.
12.	Aluminium roller		To use in inclined plane set-up.

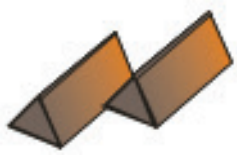
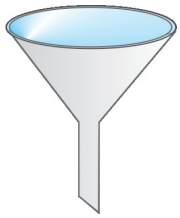
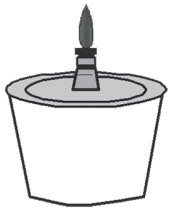
Prelims Pages.indd 12 04-01-2019 10:14:20

13.	Helical spring		To find the force constant of helical spring.
14.	50g slotted weight with hook		To measure weight of a given body using parallelogram law of vector addition.
15.	500g slotted weight with hook		For varying load while studying the variation of volume with pressure. For a sample of gas at constant temperature. For varying tension while studying the relation between frequency and length of a given wire using a sonometer.
16.	Solid wooden/ plastic block for holding beam balance and syringe		For holding beam balance. For holding syringe while studying variation of pressure with volume.
17.	Pulley (S type)		To use in parallelogram apparatus and in experiments of force of limiting friction and rolling friction etc.
18.	Steel balls		To determine coefficient of viscosity of a liquid by measuring terminal velocity.

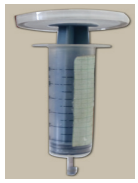
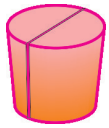
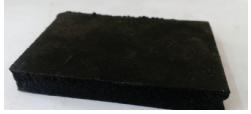
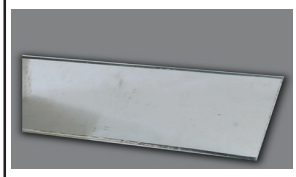
Prelims Pages.indd 13 04-01-2019 10:14:21

19.	Wooden block with hook		As a base on which weights are kept for studying rolling friction.
20.	Capillary tube		To study the effect of detergent on surface tension of water by observing capillary rise.
21.	Bob with hook		Used in experiments of simple pendulum.
22.	Plane mirror strips with scale		Used in experiments having helical spring.
23.	Watch glass		As an object for determining radius of curvature.
24.	Spring balance 250g		To measure the weight of objects.
25.	Physical weight box		To change the load in different experiments.
26.	Wires (a) Brass (b) Stainless steel (c) Nichrome		For determining relationship between frequency and length of wire in experiments of sonometer.

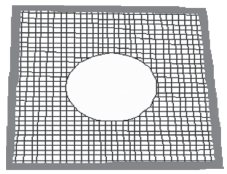
Prelims Pages.indd 14 04-01-2019 10:14:23

27.	Wooden wedge		For changing vibrating length of wire in sonometer.
28.	Set of tuning fork frequency		To determine the resonant length in sonometer.
29.	Plastic beaker (100mL and 250mL)		As container to use in specific heat capacity determination experiment.
30.	Funnel		For dropping steel ball in the liquid, while determining viscosity of a liquid.
31.	Laboratory thermometer		To measure the temperature of liquids in different experiments.
32.	Copper calorimeter with copper stirrer		To study the variation in temperature of hot water with time.
33.	Resonance tube with attachment		To determine the speed of sound in air.
34.	Tripod stand		As a stand for heating during experiments.
35.	Spirit lamp		As a heat source for carrying out experiments based on heat.

Prelims Pages.indd 15 04-01-2019 10:14:24

36.	Syringe (60mL) with wooden/ plastic top		To study the variation of volume with pressure.
37.	Plastic box		To keep different items together.
38.	Spirit level		To check whether any surface is horizontal or not.
39.	Plane glass plate		As a base for spherometer.
40.	Cotton thread		To hang a bob for making a simple pendulum.
41.	Split rubber cork		To provide a rigid support for hanging simple pendulum in which length can be easily changed.
42.	Rubber pad		As a hard surface for vibrating the tuning forces.
43.	Mirror strip		To mark direction of force in parallelogram law of vector addition experiments.
44.	Pan		For holding the weights in various experiments.

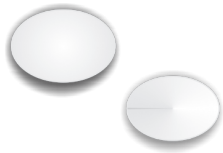
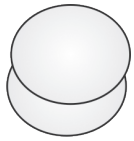
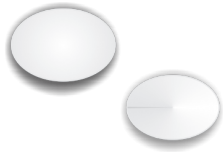
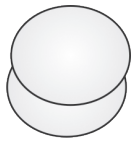
Prelims Pages.indd 16 04-01-2019 10:14:25

45.	100g weight slotted weight with hook		To study effect of load on depression of a clamped metre scale.
46.	20g slotted weight with hook		In helical spring experiments.
47.	Grease 10g		To grease the syringe.
48.	Assorted rubber band		Miscellaneous use.
49.	Wire gauge		As a base to be kept on tripod stand for uniform heating.
50.	Boiling tube fitted with glass tube in a rubber cork		To study the effect of heating on the level of a liquid.

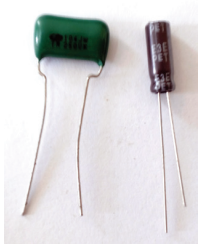
Prelims Pages.indd 17 04-01-2019 10:14:26

51.	Bimetallic strip		To observe the difference in expansion of different metals on heating.
52.	Pinch clip		As a water stopper in resonance tube assembly.
53.	Sonometer		For establishing the relationship between length of wire and frequency.
54.	Battery eliminator		As a variable dc source for use in experiments with potentiometer.
55.	Blade		To make a fine single slit to observe diffraction.
56.	Candle		As an object in studying image formation by lens/ mirror.
57.	Carbon resistor (1/2W)		As an item in mixed collection of electronic items for carrying out identification activity.

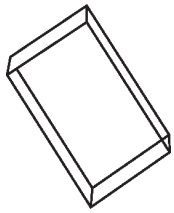
Prelims Pages.indd 18 04-01-2019 10:14:27

58.	Cartridge fuse with fuse holder		To check the continuity of a cartridge fuse.
59.	Double concave lens		For determining focal length of concave lens.
60.	Concave mirror		For determine the focal length of concave mirror. For studying the nature of image formed by a concave mirror.
61.	Connecting wires		To use as a connecting wire in meterbridge and potentiometer experiments.
62.	Double convex lens		For determining the focal length of convex lens.
63.	Convex mirror		For determining the focal length of convex mirror.
64.	Daniel cell		As a source of emf while comparing of emf of two primary cells.

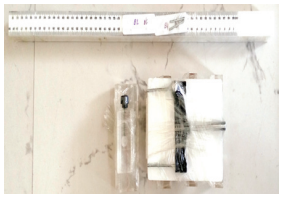
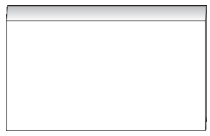
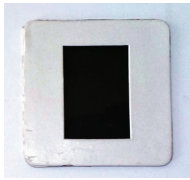
Prelims Pages.indd 19 04-01-2019 10:14:28

65.	Drawing board		As a base for performing experiments with a prism.
66.	LED		As an item in mixed collection of electronic items for carrying out identification activity.
67.	PN junction diode		As an item in mixed collection of electronic items for carrying out identification activity.
68.	Capacitor		As an item in mixed collection of electronic items for carrying out identification activity.
69.	IC		As an item in mixed collection of electronic items for carrying out identification activity.
70.	Transistor		As an item in mixed collection of electronic items for carrying out identification activity.
71.	Folding meter scale		As a part of optical bench.

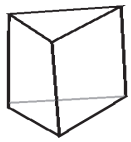
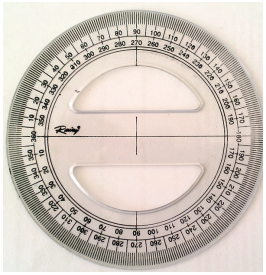
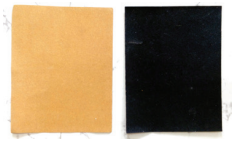
Prelims Pages.indd 20 04-01-2019 10:14:28

72.	Galvanometer		To determine the balance point in experiments with meter bridge and potentiometer.
73.	Glass slab		To observe refraction and lateral deviation.
74.	'U' shape magnet		To determine the frequency of alternating current with the help of sonometer.
75.	Jockey		To determine the null point in experiments with meter bridge and potentiometer.
76.	LDR with box		To study the variation in resistance of LDR with intensity of light.
77.	Leclanche cell		As a dc source for determining resistance per unit length of a given wire. As a dc source in experiments with meter bridge.
78.	LED torch		As a light source in studying the variation in resistance of LDR with intensity of light.
79.	Maganin wire		As a wire in experiment of converting galvanometer into ammeter and voltmeter.

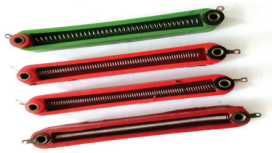
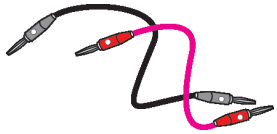
Prelims Pages.indd 21 04-01-2019 10:14:29

80.	Multimeter		To measure the various physical quantities like potential difference, resistance, current etc.
81.	Optical bench assembly		For performing the experiments with concave mirror and convex lenses.
82.	Pencil		To make a paper of given least count and to use as an object in determination of focal lengths of lens and mirrors and also as rollers in the experiment on rolling friction.
83.	Pins		To fix the white sheet of paper on drawing board.
84.	Plane mirror		To use in determination of the refractive index of liquid/water.
85.	Plug key		As a circuit breaker in different electrical experiments.
86.	Plumb line (small size)		To determine the verticality of set-up.
87.	Polaroid		To study the polarisation of light.

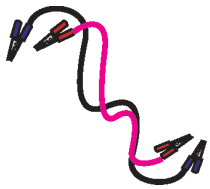
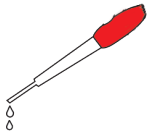
Prelims Pages.indd 22 04-01-2019 10:14:30

88.	Potentiometer		To determine the internal resistance of a cell. Used in comparing the emf of two primary cells.
89.	Prism (crown glass)		To perform the experiments on angle of minimum deviation of a prism.
90.	Full protractor		To measure the angle of incidence and angle of emergence of a beam of light incident obliquely on a glass slab.
91.	Rechargeable battery with charger		As a dc source while establishing relationship between current and voltage or in experiments with meter bridge.
92.	Resistance box		To apply a particular resistance in the circuit.
93.	Rheostat		To vary the current in an electrical circuit by changing its resistance.
94.	Sand and emery paper		Miscellaneous use.

Prelims Pages.indd 23 04-01-2019 10:14:31

95.	Set of resistor 5 Ω (one no.) 10 Ω (One no), 20 Ω (Two no's), 30 Ω (One no)		To verify the law of combination of resistors.
96.	Solenoid coil with removable iron core		To measure the resistance and impedance of an inductor with or without iron core.
97.	Straw		Miscellaneous use.
98.	Torch bulb with holder		In assembling a household circuit.
99.	Transparent glass plate		To use in experiment of diffraction of light due to a thin slit.
100.	Variable power supply		To vary the voltages for performing experiments with diodes and transistors.
101.	Zener diode		To study the characteristics of zener diode.
102.	Bread board		To build electronic circuits quickly.
103.	Banana plug connecting wire		For connecting different components of an electrical circuit.

Prelims Pages.indd 24 04-01-2019 10:14:31

104.	Crocodile clips		For connecting the different components of an electrical circuit.
105.	Glass dropper with rubber bulb		For transferring the drops of chemicals.
106.	Meter bridge		To determine the unknown resistance and specific resistance of a wire.

Prelims Pages.indd 25 04-01-2019 10:14:32

Empowerment of Girl Child, Responsibility of All

EXPERIMENT 1

AIM

Use of Vernier callipers to:

(i) measure diameter of a small spherical/cylindrical body.

(ii) measure the dimensions of a given regular rectangular solid body of known mass and to calculate its volume and density.

(iii) measure the internal diameter and depth of a given hollow cylindrical object like beaker/tumbler/calorimeter and to calculate its volume.

APPARATUS AND MATERIAL REQUIRED

Vernier callipers, spherical body such as a pendulum bob or a glass marble, rectangular or cylindrical solid of known mass and a hollow cylindrical object like a beaker/tumbler/calorimeter

PRINCIPLE

1. The difference in the magnitude of one main scale division (M.S.D.) and one vernier scale division (V.S.D.) is called the least count (L.C.) of the instrument, as it is the smallest distance that can be measured using the instrument.

   Normally, n V.S.D. = (n – 1) M.S.D.

$$1 \text{ V.S.D.} = (1 - \frac{1}{n}) \text{ M.S.D.}$$

$$\text{L.C.} = [1 - (1 - \frac{1}{n})] \text{ M.S.D}$$

$$= \frac{1\text{MSD}}{n}$$

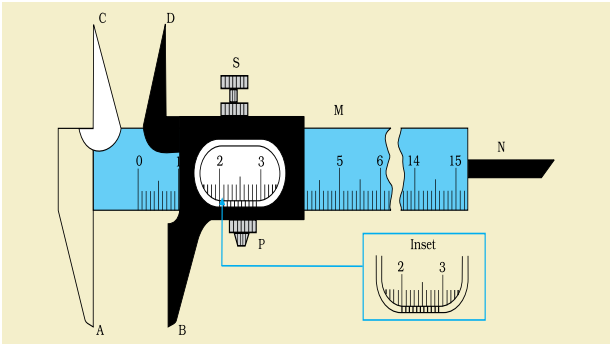


Fig. E 1.1: *Vernier callipers*

Formulae used;

(a) Least count of vernier callipers

$$= \frac{\textit{the magnitude of the smallest division on the main scale}}{\textit{the total number of the divisions on the vernier scale}}$$

(b) Density of a solid body = $\frac{mass}{volume} = \frac{m}{V} = \frac{m}{l.b.h}$ where m is its mass, l its length, b its breadth and h is the height (in case of cylindrical solid,

(c) The volume of a cylindrical (hollow) object $V = \pi r^2 h' = \frac{\pi D'^2}{4}.h'$ where h' is its internal depth, D' is its internal diameter and r is its internal radius.

PROCEDURE

(i) Measurement of L.C. of vernier calipers (V.C.)

- Find value of 1 MSD and the number of divisions on (vernier scale) V.S.(n)
- L.C. = $\frac{1\ \text{MSD}}{n}$

(ii) Measurement of zero error, if any

- Bring the two jaws of V.C. in contact. See whether the zero of V.S. coincides with zero of M.S, if yes, there is no zero error.
- If no, then see whether zero of V.S. is to the left of zero of M.S. or to the right of it. If the zero of V. S. is to the left of zero of M.S., the zero error is negative and if it is to the right of zero of M.S., the error is positive.
- Now see which division of V.S. coincides with any division of M.S., suppose it is x, then with positive zero error the corrected value =[n–(x)] × L.C. and for negative zero error the corrected value = [n–(–x)] × L.C.

(iii) (a) Measuring the diameter of a small spherical or cylindrical body.

1. Gently loosen the screw to release the movable jaw of vernier callipers. Slide it enough to hold the given sphere/cylindrical body gently (without any undue pressure) in between the lower jaws AB. The jaws should be perfectly perpendicular to the diameter of the body. Now, gently tighten the screw so as to clamp the jaws of the callipers to the body.

2. Carefully note the position of the zero mark of the vernier scale (V.S.) against the main scale (M.S.). Record the main scale reading to the left of the zero mark of the vernier scale. (In case the zero of V.S. coincides with a division of M.S., the reading of the M.S. gives the measurement.)

3. Start looking for exact coincidence of a vernier scale division with that of a main scale division from left end (zero) to the right. Note its number (say) N, carefully.

4. Multiply 'N' by least count of the instrument and add the product to the main scale reading noted in Step 2. Ensure that the product is converted into proper units (usually cm) for addition to be valid.

5. Repeat Steps 1–4 to obtain the diameter of the body at different positions on its curved surface. Take three sets of reading in each case.

6. Record the observations in the tabular form with proper units. If there is zero error in the instrument, then apply zero error correction. For this subtract zero error from the observed value with sign.

7. Find the arithmetic mean of the corrected readings of the diameter of the body. Express the results in suitable units.

(b) Measuring the dimensions of a regular rectangular solid body to determine its density.

1. Measure the length of the rectangular solid by repeating Steps 1–6 described in (a) after holding the block lengthwise between the jaws of the Vernier Callipers. In case the length of the given body extends beyond the extended jaws of the vernier callipers, measure the length using a suitable ruler.

2. Repeat Steps 1–6 stated in (a) to determine the other dimensions (breadth b and height h or the diameter D in case of cylinder) by holding the given body in proper positions.

3. Record the observations for length, breadth and height (or the length and diameter) of the rectangular block in tabular form with proper units. Apply zero corrections wherever necessary.

4. Find out the arithmetic mean of the measurements.

(c) Measuring the internal diameter and depth of the given beaker (or any other cylindrical object) to find its internal volume.

1. Adjust the outer jaws CD of the Vernier Callipers so as to touch the wall of the beaker from inside without exerting undue pressure on it. Tighten the screw gently to keep the jaws of the Vernier Callipers in this position. In case the length of the given body extends beyond the extended jaws of the vernier callipers, measure the length using a suitable ruler.
2. Repeat the steps 1-6 as in (a) to obtain the value of internal diameter of the beaker/calorimeter. Do this for two different (angular) positions of the beaker.
3. Open the jaw of the Vernier Callipers. To determine the depth of the beaker, open the jaw of the Vernier Callipers. This should be done in such a way that the tip of the strip (N) is able to go freely inside the beaker along its depth.
4. Keep sliding the moving jaw of the Vernier Callipers until the strip just touches the bottom of the beaker. Take care that it does so while being perfectly perpendicular to the bottom surface. Now tighten the screw of the Vernier Callipers.
5. Repeat steps 1 to 6 of part (a) of the experiment to obtain depth of the given beaker. Take the readings for depth at different positions of the breaker.
6. Record the observations in tabular form with proper units. Apply zero corrections, if required.
7. Find out the mean of the corrected readings of the internal diameter and depth of the given beaker. Express the result in suitable units.

OBSERVATIONS

(i) Least count of Vernier Callipers (Vernier Constant)

1 main scale division (MSD) = 1 mm = 0.1 cm

Number of vernier scale divisions, N = 10

$$\text{Vernier constant}\left(V_c\right) = \frac{1\text{MSD}}{N} = \frac{1\,\text{mm}}{10} = 0.1\,\text{mm} = 0.01\,\text{cm}$$

(ii) Zero error = ± ..... cm.

(iii) (a) Table E 1.1: Measuring the diameter of a small spherical/ cylindrical body

S. No.	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, $V = N \times V_C$ (cm/mm)	Measured diameter, $M + V$ (cm/mm)
1.				
2.				
3.				
4.				

Zero error, e = ± … cm

Mean observed diameter = … cm

Corrected diameter = Mean observed diameter – Zero Error

(b) Table E 1.2: Measuring dimensions of a given solid body (rectangular block or cylinder)

Dimension	S. No.	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading $V = N \times V_C$ (cm/mm)	Measured dimension $M + V$ (cm/mm)
Length (l)	1.				
	2.				
	3.				
Breadth (b)	1.				
	2.				
	3.				
Height (h)	1.				
	2.				
	3.				

Zero error = ± … cm

Mean observed length= … cm, Mean observed breadth = … cm

Mean observed height = … cm

Corrected length l = … cm; Corrected breadth b = … cm;

Corrected height h = …cm

(or corrected length and diameter)

(c) Table E 1.3: Measuring internal diameter and depth of a given beaker/ calorimeter/ cylindrical tumbler

Dimension	S. No.	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, $V = N \times V_C$ (cm/mm)	Measured diameter depth, $M + V$ (cm/mm)
Internal diameter (D')	1. 2. 3.				
Depth (h')	1. 2. 3.				

Mean diameter = … cm

Mean depth = … cm

Corrected diameter D′ = … cm

Corrected depth h′ = … cm

CALCULATION

(b) Volume of the rectangular block, V = lbh = … cm^3 = … m^3

Mass of the solid (given) = … g = … kg

Density of the material of the block, $\rho = \frac{m}{V} = \frac{m}{l.b.h}$ ….kg m^{-3}

(c) Internal volume of the beaker

$$V' = \frac{\pi D'^2 h'}{4} = \ldots \times 10^6 m^3$$

RESULT

(a) Diameter of the spherical/cylindrical body,

D′ = … × 10^{-2}m

(b) Density of the given solid block,

ρ = … kgm^{-3}

(c) Internal volume of the given beaker

V′ = … m^3

EXPERIMENT 2

AIM

Use of screw gauge to:

(i) measure diameter of a given wire,

(ii) measure thickness of a given sheet; and

(ii) determine volume of an irregular lamina.

APPARATUS AND MATERIAL REQUIRED

Wire, metallic sheet, irregular lamina, millimetre graph paper, pencil and screw gauge.

DESCRIPTION OF APPARATUS

Calculation of least count

Find the pitch of the screw, i.e., the distance moved by the screw in one complete rotation. If there are n divisions on the circular scale, then distance moved by the screw when it is rotated through one division on the circular scale is called the least count of the screw gauge, that is,

$$\text{Least count} = \frac{\text{pitch}}{n}$$

Calculation of zero error

When the end of the screw and the surface of the stud are in contact with each other, the linear scale and the circular scale reading should be zero. In this case there is no zero error in the instrument. If the reading of the circular scale is more than zero, that is the zero of circular scale is to the right side of the zero of linear

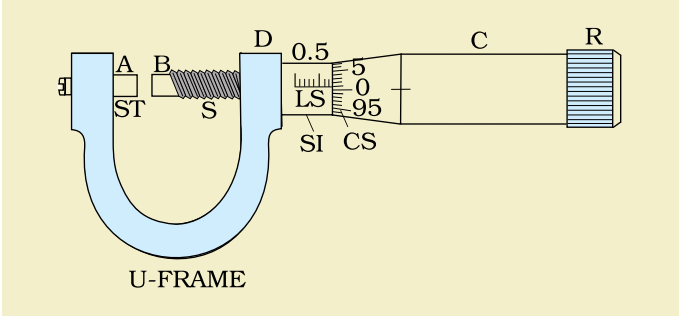


Fig.E 2.1: *View of a screw gauge*

scale, the instrument has positive zero error. Note this positive zero error. On the other hand, if the reading of the circular scale is less than zero, the instrument is said to have negative zero error, Note the negative zero error.

FORMULA USED

Total reading = Linear scale reading + circular scale reading × least count

(i) Measurement of diameter of a given wire

PROCEDURE

1. Insert the given wire between the screw and the stud of the screw gauge. Move the screw forward by rotating the rachet till the wire is gently gripped between the screw and the stud. Stop rotating the rachet the moment you hear a click sound.
2. Take the readings on the linear scale and the circular scale. Note these readings in the Table. Suppose the diameter in this position is d_1.
3. The wire may not have an exactly circular cross-section. Therefore, it is necessary to measure the diameter of the wire for two positions at right angles to each other. Rotate the wire through 90° at the same cross-sectional position. Record the reading for diameter d_2 in this position.
4. The wire may not be truly cylindrical. Therefore, it is necessary to measure the diameter at several different places and obtain the average value of diameter. For this, repeat the Steps (1) to (3) for three more positions of the wire.
5. From these readings, obtain the diameter of the wire. Take the mean of the different values of diameter so obtained.
6. Substract zero error, if any, with proper sign to get the corrected value for the diameter of the wire.

OBSERVATIONS AND CALCULATION

The length of the smallest division on the linear scale = ... mm

Distance moved by the screw when it is rotated

through x complete rotations, y = ... mm

Pitch of the screw = $\frac{y}{x}$ = ... mm

Number of divisions on the circular scale n = ...

$$\text{Least Count (L.C.) of screw guage} = \frac{\text{Pitch}}{\text{No. of divisions on the circular scale}}$$

$$\text{Least count} = \frac{\text{Pitch}}{n} = \ldots \text{ mm}$$

Zero error with sign (No. of divisions × L. C.) = … mm

Table E 2.1: Measurement of the diameter of the wire

S. No.	Reading along one direction (d_1)			Reading along perpendicular direction (d_2)			Measured diameter $a = \frac{d_1 + d_2}{2}$ (mm)
	Linear scale reading M (mm)	Circular scale reading (n)	Diameter $d_1 = M + n \times$ L.C. (mm)	Linear scale reading M (mm)	Circular scale reading (n)	Diameter $d_2 = M + n \times$ L.C. (mm)	
1							
2							
3							
4							

Mean diameter = … mm

Corrected value of mean diameter

= measured diameter–(zero error with sign) =… mm

RESULT

The diameter of the given wire as measured by screw gauge is … mm.

PRECAUTIONS

1. Rachet arrangement in screw gauge must be utilised to avoid undue pressure on the wire as this may change the diameter.
2. Move the screw in one direction else the screw may develop 'play'.
3. Screw should move freely with least friction.
4. Reading should be taken atleast at four different points along the length of the wire.
5. While taking readings keep the eye perpendicular to the scale to avoid error due to parallax.

SOURCES OF ERROR

1. The wire may not be of uniform cross-section.
2. Error due to backlash though can be minimised but cannot be completely eliminated.

(ii) Measurement of thickness of a given sheet

PROCEDURE

1. Insert the given sheet between the screw and the stud of the screw gauge and note down the linear scale and circular scale readings. Calculate the thickness of the given sheet.
2. Reapeat Step 1 at five different positions.
3. Find the average thickness and calculate the correct thickness by applying zero error following the steps adopted earlier.

OBSERVATIONS AND CALCULATION

Least count of screw gauge = ... mm

Zero error of screw gauge = ... mm

Table E 2.2 Measurement of thickness of sheet

S. No.	Linear scale reading M (mm)	Circular scale reading n	Thickness $t = M + n \times$ L.C. (mm)
1.			
2.			
3.			
4.			
5.			

Mean thickness of the given sheet = ... mm

Corrected mean thickness of the given sheet

= Observed mean thickness – (zero error with sign) = ... mm

RESULT

The thickness of the given sheet is =... mm.

(iii) Determination of volume of the given irregular lamina

PROCEDURE

1. Find the thickness of lamina as in Experiment 2(b).
2. Place the irregular lamina on a sheet of paper with mm graph. Draw the outline of the lamina using a sharp pencil. Count the total number of squares and also more than half squares within the boundary of the lamina and determine the area of the lamina.
3. Obtain the volume of the lamina using the relation mean thickness × area of lamina.

OBSERVATIONS AND CALCULATION

Same as in Experiment 2(b). The first section of the table is now for readings of thickness at five different places along the edge of the lamina. Calculate the mean thickness and make correction for zero error, if any.

From the outline drawn on the graph paper

Number of complete squares = ...

Number of half and more than half squares =...

Total number of squares (N) = ...

Area of the lamina = N × 1 mm^2
= ... mm^2

Volume of the lamina = Area × Thickness

= ... mm^3 = ... cm^3

RESULT

Volume of the given lamina = ... cm^3

EXPERIMENT 3

AIM

To determine the radius of curvature of a given spherical surface by a spherometer.

APPARATUS AND MATERIAL REQUIRED

A spherometer, a spherical surface such as a watch glass or a convex mirror and a plane glass plate of about 6 cm × 6 cm size.

PRINCIPLE

Pitch: It is the vertical distance moved by the central screw in one complete rotation of the circular disc scale.

Commonly used spherometers in school laboratories have graduations in millimetres on the main scale and may have100 equal divisions on circular disc scale. In one rotation of the circular scale, the central screw advances or recedes by 1 mm. Thus, the pitch of the screw is 1 mm.

Least Count: Least count of a spherometer is the distance moved by the spherometer screw when it is turned through one division on the circular scale, i.e., least count of the spherometer = $\frac{\text{Pitch of the spherometer screw}}{\text{Number of divisions on the circular scale}}$

The least count of commonly used spherometers is 0.01 mm.

However, some spherometers have least count as small as 0.005 mm or 0.001 mm.

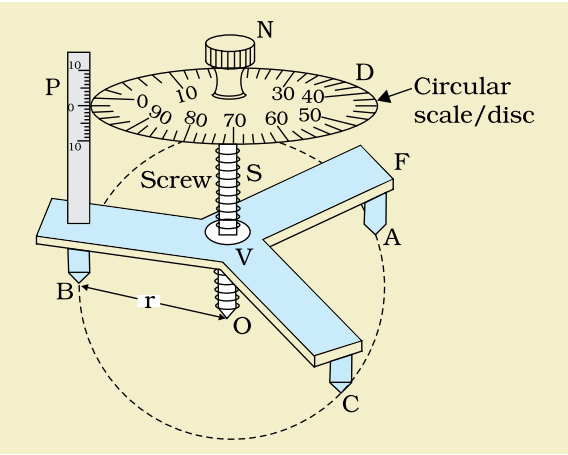


Fig. E 3.1: *A spherometer*

FORMULA USED

Radius of curvature of a spherical surface

$$R = \frac{l^2}{6h} + \frac{h}{2}$$

where, l = length between two legs of the spherometer and

h = height of central screw above the circular section ABC.

= OM (This distance OM is also called sagitta) (Fig. E 3.2)

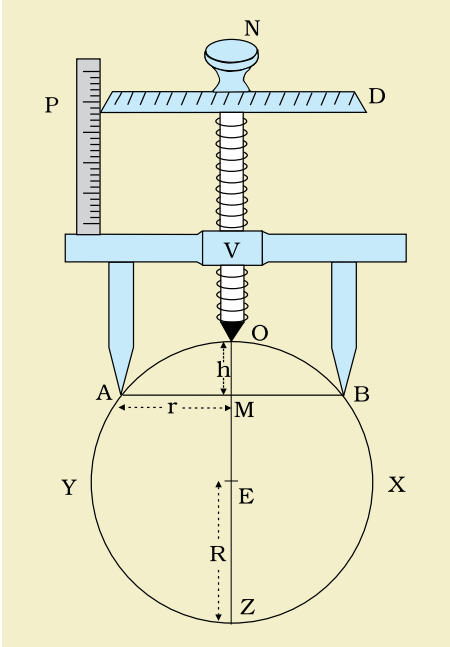


Fig. E 3.2: *Measurement of radius of curvature of a spherical surface*

PROCEDURE

1. Note the value of one division on the main scale of the given spherometer.
2. Note the number of divisions on circular scale.
3. Determine the pitch and least count (L.C.) of the spherometer. Place the given flat glass plate on a horizontal plane and keep the spherometer on it so that its three legs rest on the plate.
4. Place the spherometer on a sheet of paper (or on a page in practical note book) and press it lightly and take the impressions of the tips of its three legs. Join the three impressions to make an equilateral triangle ABC and measure all the sides of it. Calculate the mean distance *(l)* between two spherometer legs.
5. Place the given spherical surface on the plane glass plate and then place the spherometer on it by raising or lowering the central screw sufficiently upwards or downwards so that the three spherometer legs may rest on the spherical surface.
6. Rotate the central screw till it gently touches the spherical surface. To be sure that the screw touches the surface one can observe its image formed due to reflection from the surface beneath it.
7. Take the spherometer reading h_1 by noting the reading of the main scale. Also read the divisions of the circular scale that is in line with the main scale. Record the readings in Table E 3.1.
8. Remove the spherical surface and place the spherometer on plane glass plate. Turn the central screw till its tip gently touches

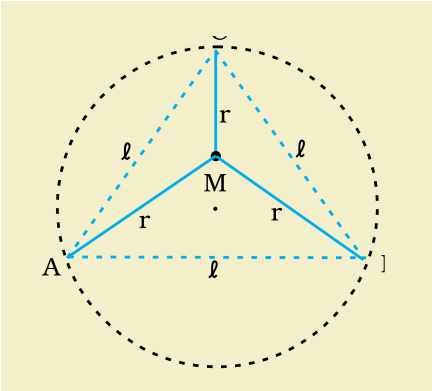


Fig. E 3.3: *The base circle of the spherometer*

the glass plate. Take the spherometer reading h_2 and record it in Table E 3.1. The difference between h_1 and h_2 is equal to the value of (h).

9. Repeat steps (5) to (8) three more times by rotating the spherical surface leaving its centre undisturbed. Find the mean value of h.

OBSERVATIONS

1. Pitch of the spherometer screw

(i) Value of smallest division on the vertical main scale = ... mm

(ii) Distance q moved by the screw for p complete rotations of the circular disc = ... mm

(iii) Pitch of the screw (= q / p) = ... mm

2. Least Count (L.C.) of the spherometer

(i) Total no. of divisions on the circular scale (N) = ...

(ii) Least count (L.C.) of the spherometer = ... cm

$$= \frac{\text{Pitch of the spherometer screw}}{\text{Number of divisions on the circular scale}}$$

$$\text{L.C.} = \frac{\text{Pitch of the screw}}{\text{N}} = \ldots\ldots\text{cm}$$

3. Determination of length *l* (from equilateral triangle ABC)

(i) Distance AB = ... cm

(ii) Distance BC = ... cm

(iii) Distance CA = ... cm

$$\text{Mean } l = \frac{\text{AB} + \text{BC} + \text{CA}}{3} = \ldots \text{ cm}$$

Table E 3.1 Measurement of h

S. No.	Spherometer Readings								$h = (h_1 - h_2)$
	With Spherical Surface				Horizontal Plane Surface				(cm)
	Main (Pitch) scale reading x (cm)	Circular scale division coinciding with pitch scale y	Circular scale reading $z = y \times$L.C. (cm)	Spherometer reading with spherical surface $h_1 = x + z$ (cm)	Main (Pitch) scale reading x' (cm)	Circular scale division coinciding with pitch scale y'	Circular scale reading $z' = y \times$L.C. (cm)	Spherometer reading with spherical surface $h_2 = x' + z'$ (cm)	

CALCULATIONS

Using the values of l and h, calculate the radius of curvature R from the formula: $R = \frac{l^2}{6h} + \frac{h}{2}$;

The term h/2 may safely be dropped in case of surfaces of large radii of curvature (in this situation error in $\left(\frac{l^2}{6h}\right)$ is of the order of h/2).

RESULT

The radius of curvature R of the given spherical surface is ... cm.

PRECAUTIONS

1. You have to be cautious whether the circular scale is moved above zero or below zero of main scale.
2. Spherometer may have backlash error. So move the screw in one direction at a time.

EXPERIMENT 4

AIM

To determine the masses of two different objects using a beam balance.

APPARATUS AND MATERIAL REQUIRED

Improvised beam balance, weight box with set of standard gravitational masses in gram and milligram ranges, forceps, spirit level and two objects whose masses are to be determined.

DESCRIPTION OF PHYSICAL BALANCE

A beam balance is a device that measures the gravitational mass of an object by comparing it with a standard gravitational mass.

The most commonly used two-pan beam balance is an application of a lever. It consists of a rigid uniform bar (beam), two pans suspended from each end, and a pivotal point in the centre of the bar (Fig. E 4.1). At this pivotal point, a support (called fulcrum) is set at right angles to the beam. This beam balance works on the principle of moments. An improvised beam balance is shown in Fig. E 4.1.

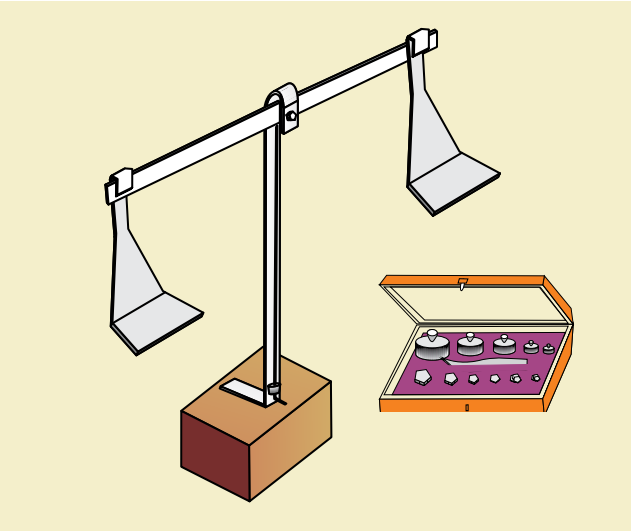


Fig. E 4.1: *A beam balance and set of weights*

If an object having gravitational mass m is placed on one pan of the beam balance and a standard mass of known value m_1 is placed on the other pan of the balance, then according to the principle of moments:

$$mg\, x_1 = m_1 g\, x_2,$$

If,

$x_1 = x_2 = x$ then, $m = m_1$

As m1 is known, it becomes possible for us to known m.

PROCEDURE

1. Examine the physical balance and recognise all the parts. Check that every part is in its proper place.
2. Check that sets of weight both in gram and milligram, in the weight box are complete.
3. Ensure that the beam stays horizontal when no weight is placed on the pans and that they are at equal distance from the fulcrum.
4. Put the object whose mass (m) is to be measured, in the left hand pan and add a suitable standard mass say m_1 (which may be more than the rough estimate of the mass of the object) in the right hand pan of the balance. Always use forceps for taking out the standard mass from the weight box and for putting them back.
5. Adjust the weights in the right hand pan till the beam becomes horizontal again.
6. Count the weights on the pan and note it in Table E 4.1. This is the mass of the first object. Take at least three measurements for the mass of the object.
7. Repeat Steps 1–6 for the second object.

OBSERVATIONS

Table E 4.1: Mass of the given object

S. No.	Standard Mass		Mass of the Object ($x + y$)
	Gram weights, x	Milligram weights, y	
	(g)	(mg)	(g)
1			
2			
3			

Mean mass of the first object = … g

Mean mass of the second object = … g

RESULT

The mass of the first given object is … g and that of the second object is =… g.

PRECAUTIONS

1. Masses should always be added in the descending order of magnitude. Masses should be placed in the centre of the pan.
2. The balance should not be loaded with masses more than its capacity. Usually a physical balance is designed to measure masses up to 250 g.
3. Weighing of hot and cold objects using a physical balance should be avoided. Similarly, substances like chemicals, liquids and powders should not be directly put on the pan.

EXPERIMENT 5

AIM

Measurement of the weight of a given body (a wooden block) using the parallelogram law of vector addition.

APPARATUS AND MATERIAL REQUIRED

The given body with hook, the parallelogram law of vector apparatus (improvised Gravesand's apparatus), strong thread, slotted weights (two sets), white paper, thin mirror strip and sharp pencil.

FORMULA USED

Let P and Q be the magnitudes of the two forces and θ the angle between them. Then the resultant R of P and Q is given by

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

If two known forces P and Q and a third unknown force R due to the weight of the given body are made to act at a point O [Fig. E 5.1 (a)] such that they are in equilibrium, then the unknown force is equal to the resultant of the two forces. Thus, the weight of a given body can be determined.

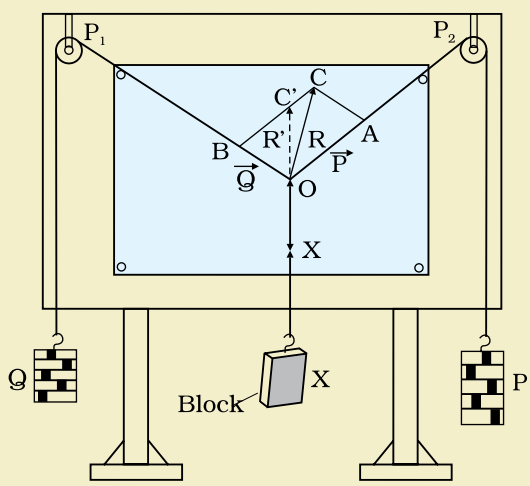


Fig. E 5.1(a): *Gravesand's apparatus*

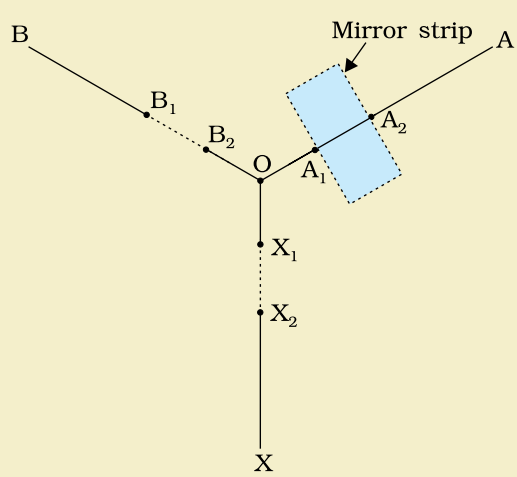


Fig. E 5.1(b): *Marking forces to scale*

PROCEDURE

1. Set the top cover of kit box in vertical position by using two rods provided in the kit. Fix the pulleys P_1 and P_2 at two edges of the top cover with s-clamp. Ensure that the pulleys are moving smoothly. This is actually our improvised Gravesand's apparatus. Fix a sheet of white paper on the wooden top cover of the kit box with drawing pins.

2. Take a sufficiently long piece of string and tie the two hangers at its ends. Tie another shorter string in the midpoint O of the first string. Tie the given body of unknown weight at the other end of the shorter string. Arrange them on the pulley as shown in Fig. E 5.1 (a) with slotted weights on the hangers. Improvised Gravesand's apparatus is now ready for use.

3. Add weights in the hangers such that the junction of the threads is in equilibrium in the lower half of the paper. Make sure that neither the weights nor the threads touch the board or the table.

4. First step is to bring the knot of the threads to position of no-friction. For this, first bring the knot to a point on extreme right or left of its position. On leaving there, it moves towards the position of no-friction because it is not in equilibrium. While it so moves, tap the board gently. The point where the knot ultimately comes to rest is taken as the position of no-friction; mark this with a point. Repeat the procedure several times. Each time let the knot approach the position of no-friction from a different direction and mark the point where it comes to rest. Find by judgment the centre of those points which are close together. Mark this centre as O.

5. To mark the direction of the force acting along a string, place a mirror strip below the string on the paper. Adjust the position of the eye such that there is no parallax between the string and its image. Mark the two points A_1 and A_2 at the edges of the mirror where the image of the string leaves the mirror [Fig. E 5.1 (b)].

   Similarly, mark the directions of other two strings, that is forces, by points B_1 and B_2 and by points X_1 and X_2 along the strings OB and OX respectively.

6. Remove the hangers and note the weight of each hanger and slotted weights on them.

7. Remove the paper from the board and place it flat on the table. Join the three pairs of points marked on the paper and extend these lines to meet at O. These three lines represent the directions of the three forces.

8. Choose a suitable scale, say 0.5 N (weight of 50 g mass) = 1cm and mark the lengths of OA and OB to represent forces P and Q respectively acting at point O according to that scale. With OA and OB as adjacent sides, complete the parallelogram OACB. Ensure that the scale chosen is such that the parallelogram covers the maximum area of the sheet.

9. Join points O and C. The length of OC will measure the weight of the given body. See whether OC is along the straight line XO. If not, let XO meet BC at some point C′. Measure the angle COC′.

10. Repeat the Steps 1 to 9 by suspending two different sets of weights and calculate the mean value of the unknown weight.

OBSERVATIONS

Weight of each hanger = ... N

Scales, 1cm = ... N

Table E 5.1: Measurement of weight of given body

S. No.	Force P = *wt* of (hanger + slotted weight)		Force Q = *wt* of (hanger + slotted weight)		Length OC = L	Unknown weight $X = L \times s$	Angle COC′
	P (N)	QA (cm)	Q (N)	OB (cm)	(cm)	(N)	
1.							
2.							
3.							

Note: The angle COC′ is indicative of error in our measurements due to unequal friction in pulleys etc.

RESULT

The weight of the given body is found to be =... N.

PRECAUTIONS

1. Board of Gravesand's apparatus should be perpendicular to the surface of the table on which it is placed. Check up with a plumb line that it is vertical. If it is not, adjust the level of kit box with suitable packing.

2. Take care that pulleys are free to rotate, i.e.,there exists little friction between the pulley and its axle.

SOURCES OF ERROR

1. Friction at the pulleys may persist even after oiling.
2. Slotted weights may not be accurate.
3. Slight inaccuracy may creep in while marking the position of the thread.

EXPERIMENT 6

AIM

Plot L – T and L – T^2 graphs for a simple pendulum and to find the effective length of second's pendulum using appropriate graph.

APPARATUS AND MATERIAL REQUIRED

Clamp stand; a split cork; a heavy metallic (brass/iron) spherical bob with a hook; a long, fine and strong cotton thread or string (about 2.0 m); stopwatch; metre scale, graph paper, pencil and eraser.

PROCEDURE

1. Place the clamp stand on the table. Tie the hook attached to the pendulum bob to one end of the string of about 150 cm in length. Pass the other end of the string through two half-pieces of a split cork.

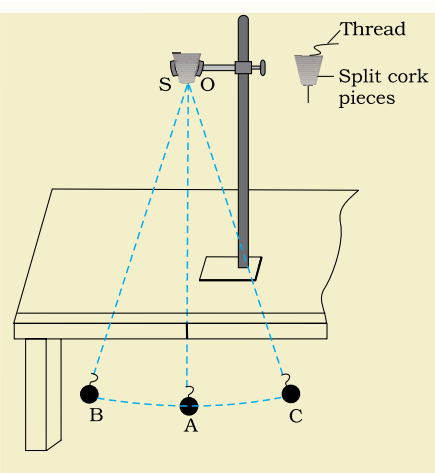


Fig. E 6. 1: *A simple pendulum; B and C show the extreme positions*

2. Clamp the split cork firmly in the clamp stand so that the pendulum hangs vertically [FigE 6.1]. Mark with a piece of chalk or ink, the point just below where the bob is at rest (called as mean position). Draw a straight line through this point along the plane of oscillation of the pendulum. Take care that the pendulum hangs vertically (about 2 cm above the floor) beyond the edge of the table so that it is free to oscillate.
3. Measure the length l of the string between the point of suspension and the top of the hook of simple pendulum.
4. Displace the bob to one side along the line drawn below it. Make sure that the angular displacement of the bob is not more than 15 degrees, from the vertical position OA and then release it gently. In case you find that the stand is shaky, put some heavy object on its

base. Make sure that the bob starts oscillating in a vertical plane about its rest (or mean) position OA and does not (i) spin about its own axis, or (ii) move up and down while oscillating, or (iii) revolve in an elliptic path around its mean position.

5. Keep the pendulum oscillating for some time. After completion of 3–5 oscillations, start the stop-watch/clock as the pendulum bob just crosses its mean position (say, from left to right). Count it as zero oscillation.

6. Keep on counting oscillations 1,2,3,..., *n*, everytime the bob crosses the mean position OA in the same direction (from left to right). Stop the stopwatch, at the count n (say, 20 or 25) oscillations, i.e., just when *n* oscillations are complete. For better results, *n* should be chosen such that the time taken for *n* oscillations is 50 s or more. Read, the total time (t) taken by the bob for *n* oscillations. Repeat this observation a few times by noting the time for same number (*n*) of oscillations. Take the mean of these readings. Compute the time for one oscillation, i.e., the time period T (= t/*n*) of the pendulum.

7. Change the length of the pendulum, by about 10 cm. Repeat the Step 6 again for finding the time (t) for about 20 oscillations or more for the new length and find the mean time period. Take 5 or 6 more observations for different lengths of pendulum and find mean time period in each case.

8. Record observations in the tabular form with proper units (Table E 6.1).

9. Take effective length L along x-axis and T^2 (or T) along y-axis, using the observed values from Table E 6.1 choose suitable scales on these axes to represent L and T^2 (or T). Plot a graph between L and T^2 (as shown in Fig. E 6.3) and also between L and T (as shown in Fig.E 6.2). L-T graph should be a best fit smooth curve.

10. Draw a line parallel to *x*-axis for T=2s, in L vs T graph to find effective length of a second's pendulum.

OBSERVATIONS

(i) Radius (r) of the pendulum bob (given) = ... cm

Length of the hook (given) (e) = ... cm

Length of pendulum string (*l*) = ... cm

Least count of meter scale = ... mm = ... cm

Least count of stopwatch = ...s

Table E 6.1: Measuring the time period T and effective length L of the simple pendulum

S. No.	Length of the string from the top of the hook of bob to the point of suspension *(l)*	Effective length, $L = (l+r+e)$		Number of oscillations counted, n	Time for n oscillations t (s)				Time period T (= t/n)
	(cm)	(cm)	m		(i)	(ii)	(iii)	Mean t (s)	s

PLOTTING GRAPHS

(i) L vs T graphs

Plot a graph between L versus T from observations recorded in Table E 6.1, taking L along *x-axis* and T along *y-axis*. You will find that this graph is a curve, which is part of a parabola as shown in Fig. E 6.2.

(i) L vs T^2 graph

Plot a graph between L versus T^2 from observations recorded in Table E 6.1, taking L along *x-axis* and T^2 along y-axis. You will find that the graph is a straight line passing through origin as shown in Fig. E 6.3.

(iii) From the T^2 versus L graph locate the effective length of second's pendulum for $T^2 = 4s^2$ (Fig. E 6.3).

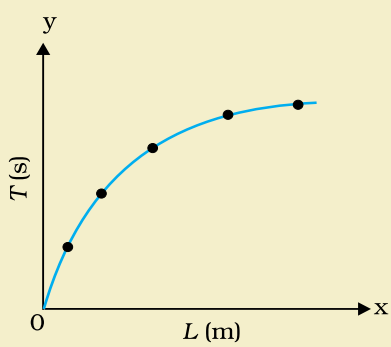


Fig. E 6.2: *Graph of L vs T*

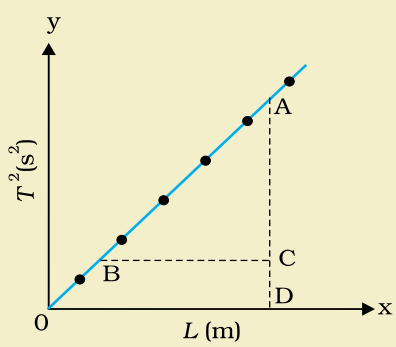


Fig. E 6.3: *Graph L vs T^2*

RESULT

1. The graph L versus T is curved, convex upwards.
2. The graph L versus T^2 is a straight line.
3. The effective length of second's pendulum from L versus T^2 graph is ... cm.

PRECAUTIONS

1. The base of the iron stand should be heavy and the base of the split cork be kept even.
2. There should not be any spinning or up and down motion during oscillations of the pendulum.
3. Time period of the pendulum should be measured accurately.
4. Remember that this relation is based on the assumption that $\sin\theta \approx \theta$, (expressed in radian) holds only for small angular displacement θ.
5. Buoyancy of air and viscous drags due to air slightly increases the time period of the pendulum. The effect can be greatly reduced to a large extent by taking a small, heavy bob of high density material (such as iron/ steel/brass).

EXPERIMENT 7

AIM

To study the relation between force of limiting friction and normal reaction and to find the coefficient of friction between surface of a moving block and that of a horizontal surface.

APPARATUS AND MATERIAL REQUIRED

A wooden block with a hook, a table with a glass or laminated top, a frictionless pulley, spirit level, a scale, pan, thread or string, spring balance, weight box and five masses of 100 g each.

FORMULA USED

The coefficient of limiting friction (μ_L) is given by $\mu_L = \frac{F_L}{R}$, where F_L is magnitude of the limiting friction and R is the magnitude of the normal force.

PROCEDURE

1. Find the range and least count of the spring balance.
2. Measure the mass (M) of the given wooden block with hook on its side and that of the scale pan (m), with the help of spring balance.

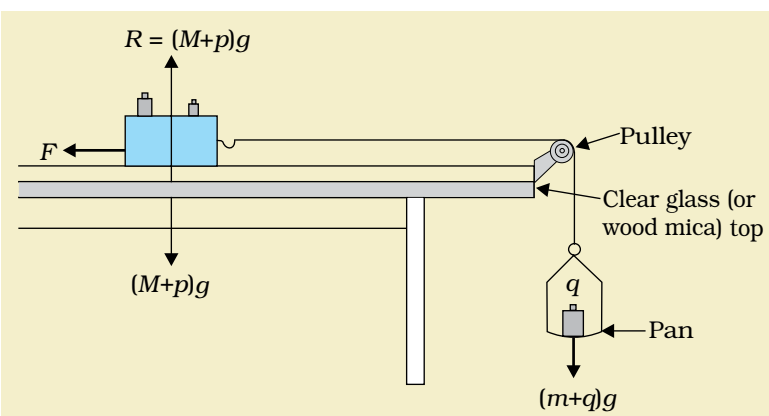


Fig. E 7.1: *Experimental set up to study limiting friction*

3. Ensure that the table-top with glass or laminated surface is horizontal. Use a spirit level for this. Take care that the top surface is clean and dry (If a table with glass or laminated top is not available, use of a glass or

laminated sheet. Ensure that the surface is horizontal. Use suitable packing, if required, to make the surface plane and horizontal).

4. Lubricate the pulley, if need.
5. Tie one end of a string of suitable length (in accordance with the size and the height of the table) to a scale pan and tie its other end to the hook of the wooden block.
6. Place the wooden block on the horizontal plane and pass the string over the pulley (Fig. E 7.1). Ensure that the portion of the string between the pulley and the wooden block is horizontal.
7. Put some mass (q) on the scale pan. Tap the table-top gently with your finger. Check whether the wooden block starts sliding.
8. Keep on increasing the mass (q) on the scale pan till the wooden block just starts sliding on gently tapping the glass top. Record the total mass kept on the scale pan in Table E 7.1.
9. Place some known mass (say p) on the top of wooden block and adjust the mass (q) on the scale pan so that the wooden block alongwith mass p just begins to slide on gently tapping the table top. Record the values of p and q in Table E 7.1.
10. Repeat Step 9 for three or four more values of p and record the corresponding values of q in Table E 7.1. A minimum of five observations may be required for plotting a graph between F_L and R.

OBSERVATIONS

1. Range of spring balance = ... to ... g
2. Least count of spring balance = ... g
3. Mass of the scale pan, (m) = ... g = ... kg
4. Mass of the wooden block (M) = ... g = ... kg
5. Acceleration due to gravity (g) at the place of experiment = ... m/s^2

Table E 7.1: Variation of limiting friction with normal reaction

S. No.	Mass on the wooden block (p)		Normal force R due to mass (M+p) g	Mass on the pan (q)		Force of limiting friction F_L $(m+q)g$	Coefficient of friction $\mu_L = \frac{F_L}{R}$	Mean μ_L
	(g)	(kg)	N	(g)	(kg)	(N)		
1.								
2.								
3.								
4.								
5.								

GRAPH

Plot a graph between the limiting friction (F_L) and normal force (R) between the wooden block and the horizontal surface, taking the limiting friction F_L along the y-axis and normal force R along the x-axis. Draw a line to join all the points marked on it (Fig. E 7.2). Some points may not lie on the straight-line graph and may be on either side of it. Extend the straight line backwards to check whether the graph passes through the origin. The slope of this straight-line graph gives the coefficient of limiting friction (μ_L) between the wooden block and the horizontal surface. To find the slope of straight line, choose two points A and B that are far apart from each other on the graph as shown in Fig. E 7.2. Draw a line parallel to x-axis through point A and another line parallel to y-axis through point B. Let point Z be the point of intersection of these two lines. Then, the slope μ_L of straight line graph AB would be

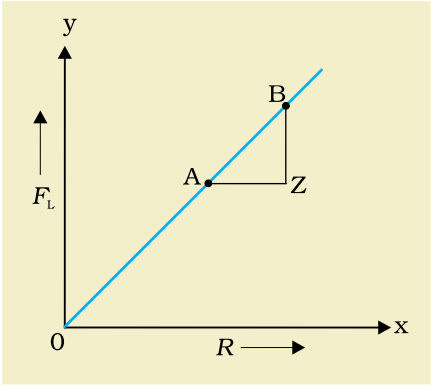


Fig. E 7.2: *Graph between force of limiting friction F_L and normal reaction R*

$$\mu_L = \frac{F_L}{R} = \frac{BZ}{AZ}$$

RESULT

The value of coefficient of limiting friction μ_L between the surface of wooden block and the table-top (laminated sheet/glass) is:

(i) From calculation (Table E 7.1) = ...

(ii) From graph = ...

PRECAUTIONS

1. Surface of the table should be horizontal and dust free.
2. Thread between the wooden block and the pulley should be horizontal.
3. Friction of the pulley should be reduced by proper oiling.
4. Table top should always be tapped gently.

SOURCES OF ERROR

1. Always put the mass at the centre of the wooden block.
2. Surface must be dust free and dry.
3. The thread must be unstretchable and unspun.

EXPERIMENT 8

AIM

To find the downward force due to gravity acting on a roller along an inclined plane, and to study its relationship with the angle of inclination 'θ' by plotting graph between force and sin θ.

APPARATUS AND MATERIAL REQUIRED

Inclined plane with protractor and pulley, roller, weight box, spring balance, spirit level, pan and thread.

PROCEDURE

1. Find the mass of the roller M_1 and mass of the pan M_2 with the help of spring balance.
2. Arrange the inclined plane on a horizontal surface. Place the roller and the masses in the pan as shown in Fig. E 8.1. Ensure that pulley is frictionless. Lubricate it using machine oil, if necessary.
3. To start with, let the value of mass M_3 on the pan be adjusted so as to permit the roller to stay at the top of the inclined plane at rest.
4. Start decreasing the masses in small steps in the pan until the roller just starts moving down the plane with a constant velocity. Note the value of mass M_3 and also the angle θ.

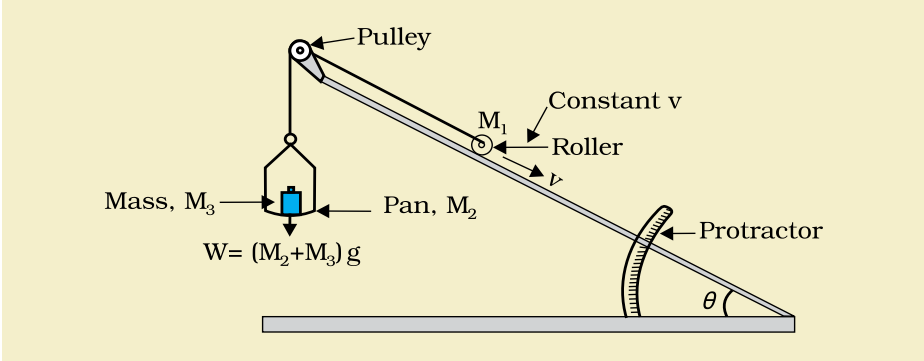


Fig. E 8.1: *Experimental set up to find the downward force along an inclined plane*

5. Repeat Steps 3 and 4 for at least three more different values of θ. Tabulate your observations.

OBSERVATIONS

Acceleration due to gravity, g = ... ms^{-2}

Mass of roller, M_1 = ... g

Mass of the pan M_2 = ... g

Table E 8.1

S. No.	θ	sinθ	Mass on the pan M_3	Force $W = (M_2 + M_3)\, g$ (N)
1				
2				
3				

PLOTTING GRAPH

Plot graph between sin θ and the force W (Fig. E 8.2).

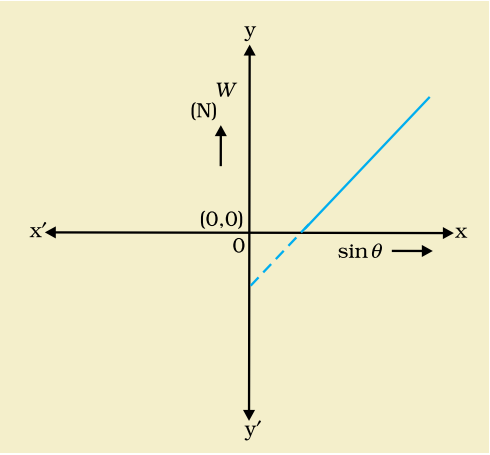


Fig. E 8.2: *Graph between W and sinθ*

RESULT

The graph between downward force W and sinθ is a straight line. Therefore, within the experimental error, downward force along inclined plane increases with the increase in sinθ, where θ is the angle of inclination of the plane as shown in Fig E 8.1.

PRECAUTIONS

1. Ensure that the inclined plane is placed on a horizontal surface using the spirit level.
2. Pulley must be frictionless.
3. The pan should be suspended freely without touching the table or other objects.

EXPERIMENT 9

AIM

To find the force constant and effective mass of a helical spring by plotting T^2 - m graph using method of oscillation.

APPARATUS AND MATERIAL REQUIRED

Light weight helical spring with a pointer attached at the lower end and a hook/ring attached to the other end for suspending a hanger from it, a rigid support, a hanger and five slotted weights of 10 g each (in case the spring constant is of high value one may use slotted weight of 20 g), clamp stand, a balance, a measuring scale (15–30 cm) and a stopwatch (with least count of 0.1s).

FORMULA USED

Force constant of spring, $K = \dfrac{4\pi^2 (m_1 - m_2)}{T_1^2 - T_2^2}$

Here, m_1 and m_2 are masses of two different objects suspended from the spring and T_1 and T_2 are their respective periods of oscillations.

PROCEDURE

1. Suspend the helical spring SA (having pointer P and the hanger H at its free end A) from a rigid support, as shown in Fig E 9.1
2. Set the measuring scale close to the spring, vertically. Take care that the pointer P moves freely over the scale without touching it.
3. Find out the least count of the measuring scale. (It is usually 1mm or 0.1 cm.)
4. Familiarise yourself with the working of the stopwatch and find its least count.

5. Suspend the hanger and gently place on it a load or a slotted weight of mass m_1. Wait till the pointer comes to rest. This is the equilibrium position for the given load. Pull the load slightly downwards and then release it gently so that it is set into oscillations in a vertical plane about its rest (or equilibrium) position. The rest position (x) of the pointer P on the scale is the reference or mean position of oscillations for the given load. Start the stopwatch as the pointer P just crosses its mean position (say, from upwards to downwards) and simultaneously begin to count the oscillations.

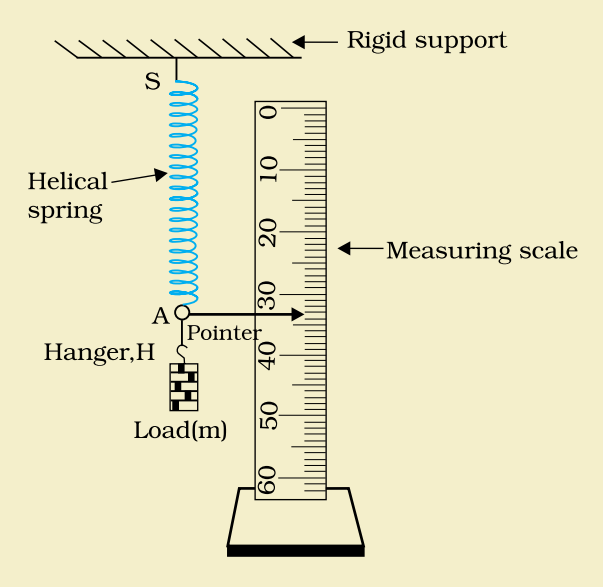


Fig. E 9.1: *Experimental arrangement for studying spring constant of helical spring.*

6. Keep on counting the oscillations as the pointer crosses the mean position (x) in the same direction. Stop the watch after n (say, about 10) oscillations are complete. Note the time (t) taken by the oscillating load for n oscillations.

7. Repeat this observation alteast thrice and in each occasion note the time taken for the same number (n) of oscillations. Find the mean time (t_1), for n oscillations and compute the time for one oscillation, i.e., the time period T_1 (= t_1/n) of oscillating helical spring with a load m_1.

8. Repeat Steps 5 to 7 for two more slotted weights.

9. Calculate the time period of oscillation for each weight and tabulate your observations.

10. The value of K can be determined by plotting a graph between T and m with T on y-axis and m on x-axis.

11. The value of force constant (K_1, K_2, K_3) of the spring for each load can be computed by using the formula where m_1 and m_2 are two different masses and T_1 and T_2 are their respective periods of oscillations. Find out the mean value of force constant K of the given helical spring. Compare the value of force constant obtained from the graph with that computed mathematically.

Note: The number of oscillations, *n*, should be large enough to keep the error minimum in measurement of time. One convenient method to decide on the number *n* is based on the least count of the stopwatch. If the least count of the stopwatch is 0.1s. Then to have 1% error in measurement, the minimum time measured should be 10.0s. Hence, the number *n* for oscillations should be so chosen that oscillating mass takes more than 10.0s to complete them.

OBSERVATIONS

Least count of the measuring scale = ... mm = ... cm

Least count of the stopwatch = ... s

Mass of load 1, m_1 = ... g = ... kg

Mass of load 2, m_2 = ... g = ... kg

Mass of load 3, m_3 = ... g = ... kg

Table E 9.1: Measuring the time period T of oscillations of helical spring with load

S. No.	Mass of the load, m (kg)	Mean position of pointer, x (cm)	Number of oscillations (n)	Time for (n) oscillations t (s)				Time period T=t/n (s)
				t_1	t_2	t_3	mean $t = \frac{t_1 + t_2 + t_3}{3}$	

CALCULATION

Substitute the values of m_1, m_2, m_3 and T_1, T_2, T_3, in formula:

$K_1 = 4\pi_2 (m_1 - m_2)/(T_1^2 - T_2^2)$;

$K_2 = 4\pi_2 (m_2 - m_3)/(T_2^2 - T_3^2)$;

$K_3 = 4\pi_2 (m_1 - m_3) / (T_1^2 - T_3^2)$

To find the force constant and the effective mass of the spring plot the graph between T^2 and m, which is expected to be a straight line as shown in Fig E 9.2.

The value of spring constant K (= $4\pi^2 m/T^2$) of the helical spring can be calculated from the slope m′ of the straight line graph.

Slope, m′ = tanθ = OD/OE = c/c′ = –c/m_o = $(4\pi^2/K)$]

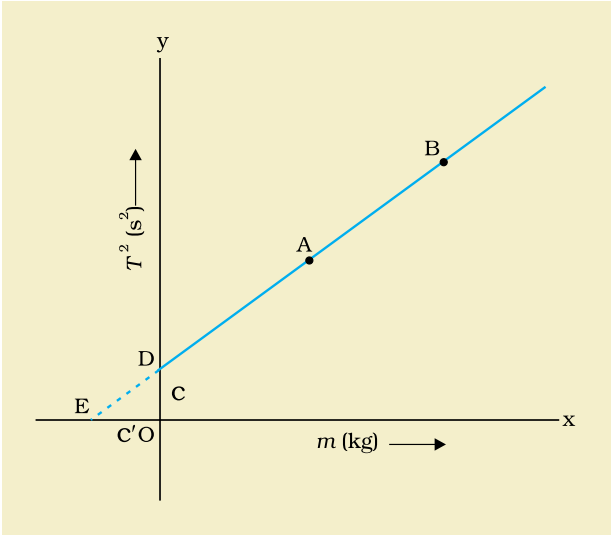


Fig. E 9.2: *Expected graph between T^2 and m for a helical spring*

From the knowledge of intercept c on y-axis and the slope m′ the value of effective mass m_o (= c/m′) of the helical spring can be computed. Alternatively, the effective mass m_o (= –c′) of the helical spring can be directly computed from the knowledge of the intercept c′ made by the straight line on x-axis.

RESULT

1. Spring constant of the given helical spring = … N/m
2. Effective mass of helical spring = … g = … kg

PRECAUTIONS

1. Take care that the spring hangs vertically and the pointer is light and attached horizontally.
2. The scale should be held vertically.
3. The stand should have a heavy base and the support should be rigid.

EXPERIMENT 10

AIM

To study the variation of volume (V) with the pressure (P) for a sample of air at constant temperature by plotting graphs between P and V and that between P and $\frac{1}{V}$.

APPARATUS AND MATERIAL REQUIRED

A 60 mL syringe (with known internal area of cross-section and mass of the piston, m_p) having a rubber tubing fixed at its nozzle; a wooden block with a hole to hold the syringe in vertical position; plastic disc of known mass with a slot that fits into the top of the piston of syringe; slotted weights of 500 g; thread; single pan balance; strip of 10 cm×2 cm graph paper; glue or tape; grease and laboratory stand with clamp.

PROCEDURE

1. Remove the piston from the syringe and grease it properly. Put the piston back in the syringe. Now block the nozzle of the syringe with your finger and press the piston. Ensure that the piston comes back to its initial position on releasing the pressure.
2. Fix the rubber tube onto the nozzle of the syringe and fold it. Tie the rubber tube tightly with a thread to make it airtight.
3. Fix a 10cm × 2cm strip of graph paper along the length of the syringe using glue or a tape.
4. Clamp the syringe vertically on a laboratory stand. Now place the wooden block with a cavity just below the nozzle of the syringe. Adjust the height of the syringe such that its nozzle firmly stands on the wooden block as shown in Fig E10.1.
5. Next fix the plastic disc with a slot onto the top of the piston (Fig E10.1). Again check whether the piston comes back to its initial position after it is pressed and released. Your apparatus to study variation of volume of air with pressure is now ready.

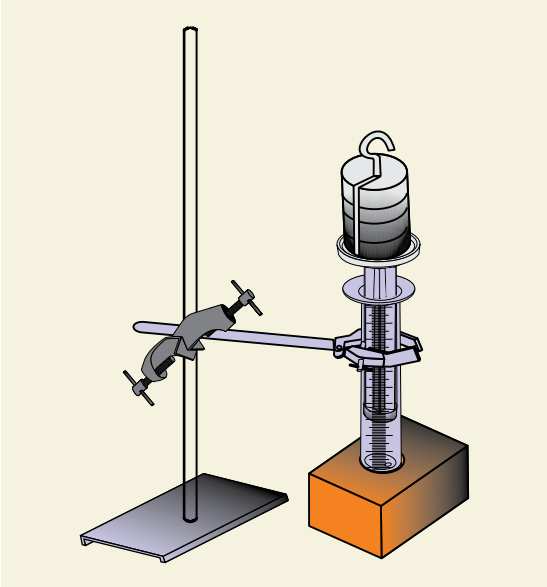


Fig. E 10.1: *Boyle's law appratus*

6. Note the position of the rim of the piston (it is better to note the position of the rim of the piston in contact with the wall of syringe rather than the piston tip at the centre).
7. Now place a 500 g mass on the wooden block fixed at the top of piston. Wait for a few seconds to let the piston settle in its new position. Note the new position of the rim of the piston from the bottom of the syringe.
8. Repeat Step 7 by increasing the mass on top of the piston in steps of 500 g and note the corresponding position of the piston in each case.
9. Now remove one by one the 500 g mass from the top of the piston. Again note the position of the piston in each case.
10. By using the formula given in Table E10.1, PV can be calculated.
11. Since in this setup 'A' is fixed therefore P $\propto$ m and V $\propto (l - l_1)$. Graphs between m vs $(l - l_1)$ and m vs $\frac{1}{(l - l_1)}$ will be similar graphs between P vs V and P vs $\frac{1}{V}$ respectively.

OBSERVATIONS

1. Room temperature =.... °C
2. Acceleration due to gravity g = ... ms^{-2}

Table E 10.1: Measurement of Pressure and Volume of enclosed air

S. No.	Weight kept on piston (m)		Position of rim of piston (cm)			$l - l_1$ (cm)	$\frac{1}{(l - l_1)}$	$PV = \left[\left(P_A + \frac{m_p + m_w + m}{A} g\right) - \left(P_A + \frac{m_p + m_w}{A} g\right)\right] \times (l - l_1) A = mg(l - l_1)$
	(kg)	(N)	During increasing weight x_1 (cm)	During decreasing weight x_2 (cm)	Mean $l_1 = \frac{x_1 + x_2}{2}$ (cm)			
1.								
2.								
3.								

3. Atmospheric Pressure, P_A at STP= 1.01×10^5 Pa.
4. Area of internal cross-section of the syringe A (given) πr^2= … cm^2 ($6.34\times10^{-4}m^2$)
5. Initial height of air column in the syringe l = … cm = …m
6. Initial volume of air enclosed in the syringe= = …m^3
7. Mass of the piston (given) = $m_p$kg
8. Mass of the plastic disc at top of piston (given)=$m_w$kg

PLOTTING OF GRAPH

It is clear in this setup that the change in pressure is $P = \frac{mg}{A}$ i.e, $P \propto m$ for fixed 'A'.

Similarly, change in volume v = $(l-l_1)$A, i.e., $v \propto (l-l_1)$ for fixed 'A'. Therefore, nature of graph between P and V will be similar to graph between m and $(l-l_1)$ (Fig. E 10.2) and between P and $\frac{1}{V}$ will be similiar to graph between m and $\frac{1}{(l-l_1)}$ Fig. E 10.3.

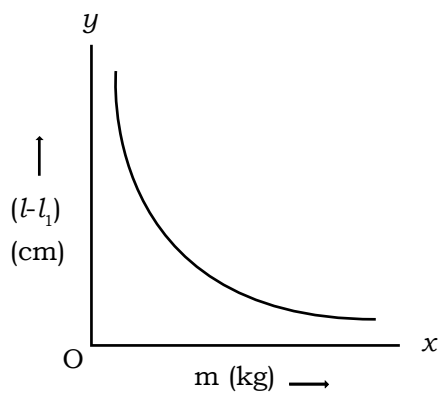


Fig. E 10.2: *Graph between m and* $(l-l_1)$

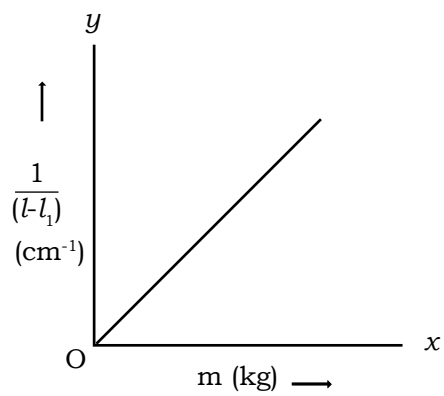


Fig. E 10.3: *Graph between m and* $\frac{1}{(l-l_1)}$

RESULT

1. Within experimental limit the graph between P ($P \propto m$) and V [$v \propto (l-l_1)$] is a part of a hyperbola.
2. Within experimental limits the product PV is a constant.
3. The graph between P and $\frac{1}{V}$ is a straight line which suggests that the pressure of a given mass of enclosed gas is inversely proportional to its volume at constant temperature.

PRECAUTION

1. The syringe should be fixed vertically and should remain so during the experiment.
2. The load should be kept at the centre of the top of the piston.
3. While taking readings the eye should be kept at the level of the lower rim of the piston.
4. After every loading on top of the piston wait for a few seconds before taking the reading. This would ensure to some extent that temperature remains constant.

EXPERIMENT 11

AIM

To determine the coefficient of viscosity of a given liquid by measuring the terminal velocity of a spherical body.

APPARATUS AND MATERIAL REQUIRED

A wide bore tube of transparent glass/acrylic (approximately 60 cm long and 4 cm diameter), an inlet tube of about 10 cm length and 1 cm diameter (or a funnel with an opening of 1 cm), a set of steel balls of different known diameters between 1.0 mm to 3 mm, 1L transparent viscous liquid (castor oil/glycerine), laboratory stand, forceps, rubber bands, two rubber stoppers (one with a hole), a laboratory thermometer, metre scale, two stopwatches and a strong magnet.

FORMULA USED

The terminal velocity v is given by

$$v = \frac{\frac{4}{3}\pi r^3 (\sigma - \rho) g}{6\pi\eta r} = \frac{2}{9} r^2 \frac{(\sigma - \rho) g}{\eta} \qquad \text{(E 11.1)}$$

$$\eta = \frac{2}{9} g(\sigma - \rho).\frac{r^2}{v} = \frac{2}{9}\frac{(\sigma - \rho) g}{(\text{slope of } \vartheta v \text{s } r^2 \text{ graph})} = \ldots \text{Nsm}^{-2} (\text{poise}) \qquad \text{(E 11.2)}$$

Where, r is the radius of spherical ball; σ and ρ are the density of the spherical balls and liquid respectively. η is the viscosity of the liquid; g is the acceleration due to gravity.

The relation given by the equation (E 11.2) holds good if the liquid through which the spherical body falls freely is in a cylindrical vessel of radius $R >> r$ and the height of the cylinder is sufficient enough to let the ball attain terminal velocity. At the same time the ball should not come in contact with the walls of the vessel.

PROCEDURE

1. Find the least count of the stopwatch.
2. Note the room temperature, using a thermometer.
3. Take a wide bore tube of transparent glass/acrylic (of diameter about 4 cm and of length approximately 60 cm). Fit a rubber stopper at one end of the wide tube and ensure that it is airtight. Fill it with the given transparent viscous liquid (say glycerine). Fix the tube vertically in the clamp stand as shown in Fig. E 11.1 Ensure that there is no air bubble inside the viscous liquid in the wide bore tube.
4. Put three rubber bands A, B, and C around the wide bore tube dividing it into four portions (Fig. E 11.1), such that AB = BC, each about 15 cm. The rubber band A should be around 20 cm below the mouth of the wide bore tube (length sufficient to allow the ball to attain terminal velocity).
5. Separate a set of clean and dry steel balls of different radii. The set should include four or five identical steel balls of each known radii (r_1). Rinse these balls thoroughly with the experimental viscous liquid (glycerine) in a petridish or a watch glass. Otherwise these balls may develop air bubble(s) on their surfaces as they enter the liquid column.

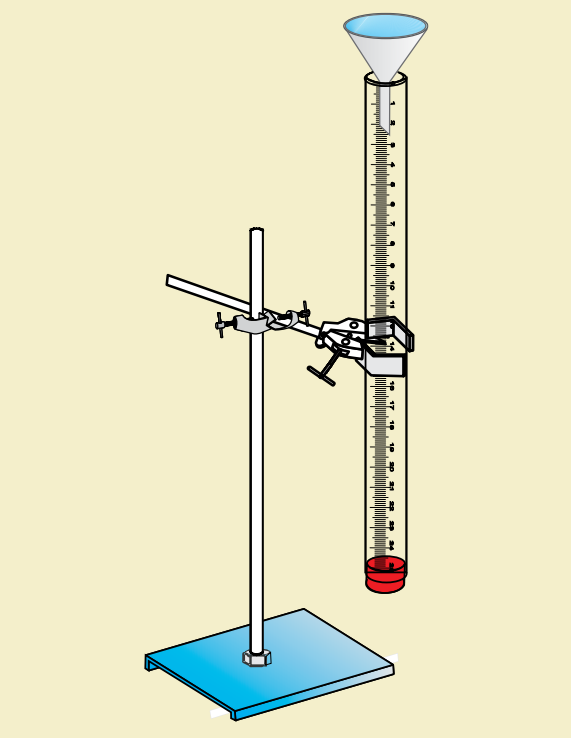


Fig.E 11.1: *Steel ball falling along the axis of the tube filled with a viscous liquid*

6. Fix a short inlet tube vertically at the open end of the wide tube through a rubber stopper fixed to it. Alternately one can also use a glass funnel instead of an inlet tube as shown in Fig. E 11.1. With the help of forceps hold one of the balls of radius r_1 near the top of tube. Allow the ball to fall freely. The ball, after passing through the inlet tube, will fall along the axis of the liquid column.
7. Take two stopwatches and start both of them simultaneously as the spherical ball passes through the rubber band A. Stop one of the watches as the ball passes through the band B.

Allow the second stopwatch to continue and stop it when the ball crosses the band C.

8. Note the times t_1 and t_2 as indicated by the two stopwatches, t_1 is then the time taken by the ball to fall from A to B and t_2 is the time taken by it in falling from A to C. If terminal velocity had been attained before the ball crosses A, then $t_2 = 2\ t_1$. If it is not so, repeat the experiment with steel ball of same radii after suitably lowering the positions of rubber bands.
9. Repeat the experiment for other balls of different diameters. Record your observations in Table E 11.1.
10. Obtain terminal velocity for each ball as $\upsilon = \dfrac{\text{Distance AC}}{t_2}$
11. Plot a graph between terminal velocity, υ and square of the radius of spherical ball, r^2. It should be a straight line. Find the slope of the line and hence determine the coefficient of viscosity of the liquid using the relation given by the equation (E 11.2).

OBSERVATIONS AND CALCULATIONS

1. Temperature of experimental liquid (glycerine) θ = ...°C.
2. Density of material of steel balls (given) σ = ... kg m^{-3}
3. Density of the viscous liquid used in the tube (given) ρ= ... kgm^{-3}
4. Length of the wide bore tube = ... cm = ... m
5. Distance between A and B = ... cm = ... m
6. Distance between B and C = ... cm = ... m

   Average distance h between two consecutive rubber bands = ... cm = ... m
7. Acceleration due to gravity at the place of experiment, g = ... ms^{-2}
8. Least count of stopwatch = ... s

Table E 11.1: Measurement of time of fall of steel balls

S. No.	Diameter of spherical balls d (cm)	$r=d/2$ (m)	Square of the radius of the balls r^2 (m^2)	Time taken for covering distance h = ... cm between rubber bands				Terminal Velocity $\upsilon = \dfrac{h}{t}$ (ms^{-1})
				A and B t_1 (s)	A and C t_1 (s)	B and C $t_3=t_2-t_1$ (s)	Mean time $t = \dfrac{t_1+t_3}{2}$ (s)	
1.								
2.								
3.								

GRAPH

Plot a graph between r^2 and v taking r^2 along x-axis and v along y-axis.

$$\eta = \frac{2}{9}\frac{(\sigma - \rho)g}{(\text{slope of the graph})}$$

RRSULT

The coefficient of viscosity of the given viscous liquid at temperature

$\theta°C$ = ... Nsm^{-2}

PRECAUTIONS

1. In order to minimise the effects, although small on the value of terminal velocity (more precisely on the value of viscous drag, force F), the radius of the wide bore tube containing the experimental viscous liquid should be much larger than the radius of the falling spherical balls.
2. The steel balls should fall without touching the sides of the tube.
3. The ball should be dropped gently in the tube containing viscous/ liquid.

EXPERIMENT 12

AIM

To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

APPARATUS AND MATERIAL REQUIRED

Improvised apparatus for Newton's law of cooling that includes a copper calorimeter fitted inside the another container which is fixed in a cylinderical vessel. (The insulating lid of both calorimeter and outer container have three holes of which two are for inserting the two thermometers and one for a stirrer), a stopwatch, a heater, a liquid (water), a tripod stand and a small container to heat water.

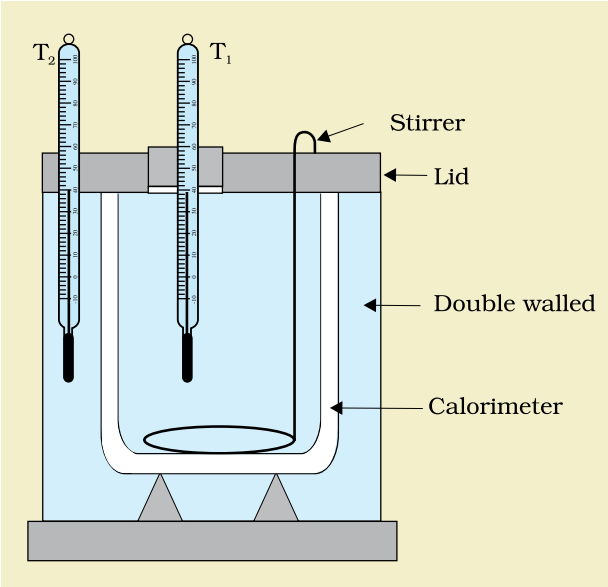


Fig E 12.1: Improvised apparatus to study Newton's law of cooling

DESCRIPTION OF APPARATUS

As shown in Fig E 12.1, the improvised apparatus to study the law of cooling has a calorimeter placed in a bigger container, the two together act as a double walled container. It can be closed by an insulating lid. Water filled between walls of the two containers ensures that the temperature of the environment surrounding the calorimeter does not fall rapidly so that the temperature measurement is feasible. Temperature of water in calorimeter and that of water between walls of the two containers is recorded by two separate thermometers.

PROCEDURE

1. Find the least counts of thermometers T_1 and T_2.
2. Familiarise yourself with the working of the stopwatch given in the kit and find its least count.

3. Pour water into the space between the calorimeter and the outer container (enclosure) at room temperature. Insert the thermometer T_2 in water contained in it.
4. Heat some water separately to a temperature of about 40°C above the room temperature θ_0. Pour hot water in calorimeter up to its height. Cover it with the lid having holes. Insert the thermometer T_1 and the stirrer in the calorimeter through the holes provided in the lid, as shown in Fig. E 12.1.
5. Note the initial temperature θ_1 of the water between the double walls with the help of thermometer T_2, note the initial reading θ of the thermometer T_1.
6. Keep on gently stirring the water in calorimeter. Note the reading of thermometer T_1, first after about every half a minute, then after about one minute and finally after two minutes duration or so. Start the stopwatch when the first measurement of temperature is taken by thermometer T_1.
7. Keep on simultaneously noting the reading of the stopwatch and that of the thermometer T_1, while stirring water gently and constantly, till the temperature of water in the calorimeter falls to a temperature of about 5°C above that of the water in the outer enclosure θ_2. Note the temperature of the water in the outer enclosure, by the thermometer T_2.
8. Record observations in Table E 12.1. Find the excess of temperature $(\theta - \theta_0)$ and also $\log_{10} (\theta - \theta_0)$ for each reading, using logarithmic tables. Record these values in the corresponding columns in the table.
9. Plot a graph between time t, taken along x-axis and $(\theta - \theta_0)$ taken along *y*-axis.

OBSERVATIONS

Initial temperature of water between the double walls, q_1=...°C

Final temperature of water between the double walls, q_2=...°C

Mean temperature of water between the double walls, $q_0 = \frac{\theta_1 + \theta_2}{2}$ =...°C

Table E 12.1: Measuring the change in temperature of water with time

S. No.	Time (*t*) (s)	Temperature of hot water θ°C	Excess *Temperature of ot water* ($\theta - \theta_o$)	$\log_{10} [\theta - \theta_o]$
1.				
2.				
-				
-				
20.				

PLOTTING GRAPH

(i) Plot a graph between $(\theta - \theta_0)$ and time t taking t along *x*-axis and $(\theta - \theta_0)$ along y-axis. It will be like the graph shown in Fig. E 12.2 This is called cooling curve.

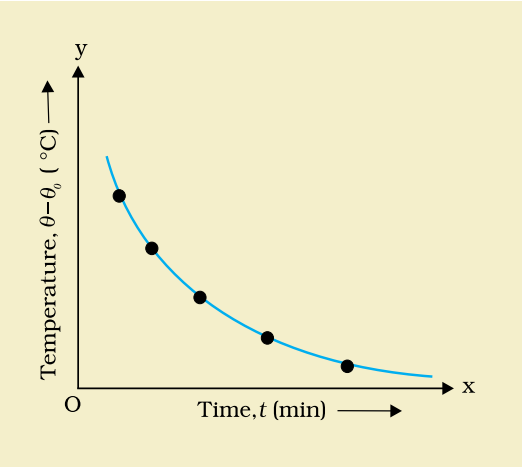


Fig. E 12.2: *Graph between* $(\theta - \theta_0)$ *and t for cooling*

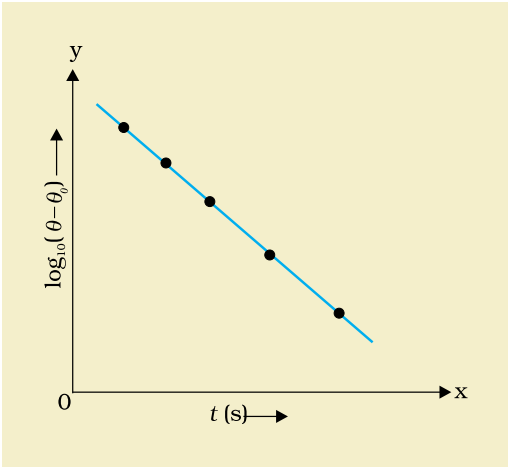


Fig. E 12.3: *Graph between* $\log_{10}(\theta - \theta_0)$ *and t*

RESULT

The cooling curve is an exponential decay curve.

PRECAUTIONS

1. The water in the calorimeter should be gently stirred continuously.
2. Ideally the space between the double walls of the surrounding vessel should be filled with flowing water to make it an enclosure having a constant temperature.
3. Make sure that the openings for inserting thermometers and the stirrer are airtight and no heat is lost to the surroundings through these.
4. The starting temperature of water in the calorimeter should not be less than 30°C above the room temperature.

Note: If a graph is plotted between $\log_{10}(\theta - \theta_0)$ and time t, taking t on x-axis and $\log_{10}(\theta - \theta_0)$ on y-axis with suitable scales. We will get a straight line as shown in Fig. E 12.3. The graph clearly shows that the logarithm of the excess of temprature of hot body over that of its surrounding varies linearly with time as the body cools.

EXPERIMENT 13

AIM

(i) To study the relation between frequency and length of a given wire under constant tension using a sonometer.

(ii) To study the relation between the length of a given wire and tension for constant frequency using a sonometer.

APPARATUS AND MATERIAL REQUIRED

Sonometer, six tuning forks of known frequencies, metre scale, rubber pad, paper rider, hanger with half-kilogram weights, and wooden wedges.

DESCRIPTION OF APPARATUS

Sonometer

It consists of a long sounding board or a hollow wooden box with a peg G at one end and a pulley at the other end as shown in Fig. E13.1. One end of a metal wire is attached to the peg and the other end passes over the pulley P. A hanger H is suspended from the free end of the wire. By placing slotted weights on the hanger tension is applied to the wire. By placing two wedges A and B under the wire, the length of the vibrating wire can be fixed. Position of one of the wedges, say wedge A is kept fixed so that by varying the position of other wedge, say wedge B, the vibrating length can be altered.

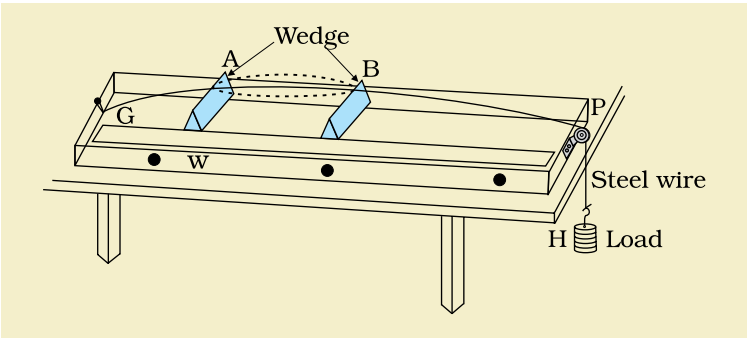


Fig. E 13.1: *Experimental setup for determining specific heat of a given solid*

PROCEDURE

1. Set up the sonometer on the table and clean the groove on the pulley to ensure that it has minimum friction. Stretch the wire by placing a suitable load on the hanger.

2. Place a small paper rider in the middle of wire AB between the two wedges. Sound the tuning fork by striking it against a rubber pad and place its shank stem on the wedge A or on the sonometer box. Slowly adjust the position of wedge B till the paper rider is agitated violently, which indicates resonance.

   The length of the wire between A and B is the resonant length such that its frequency of vibration of the fundamental mode equals to the frequency of the tuning fork (n). Measure this length l with the help of a metre scale.

3. Repeat the above procedures for other five tuning forks keeping the load on the hanger unchanged. Plot a graph between n and l (Fig. E 13.2).

4. Also, plot a graph between n and $1/l$, where l is the resonating length (Fig. E 13.3).

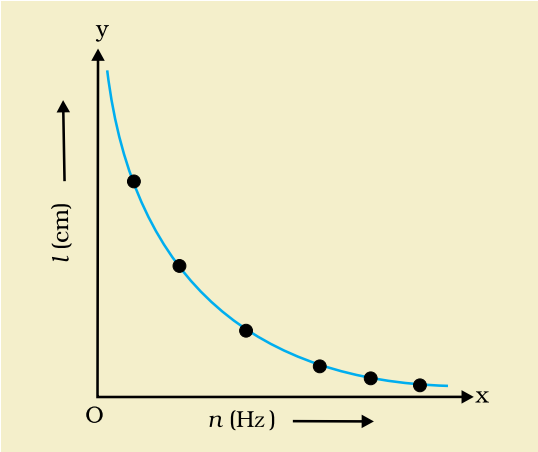


Fig. E 13.2: *Variation of resonant length with frequency of tuning fork*

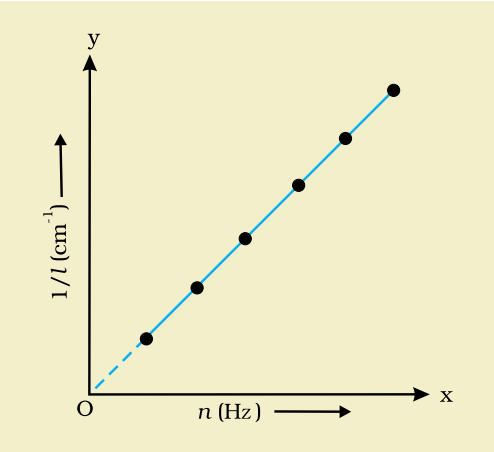


Fig. E 13.3: *Variation of $1/l$ with n*

OBSERVATION

Tension (constant) on the wire (weight suspended from the hanger including its own weight) T = ... N

Table E 13.1: Variation of frequency with length

Frequency n of tuning fork (Hz)	n_1	n_2	n_3	n_4	n_5	n_6
Resonating length l (cm)						
$\frac{1}{l}$ (cm^{-1})						
nl (Hz cm)						

CALCULATIONS AND GRAPH

Calculate the product nl for each tuning fork and calculate the reciprocals $1/l$, of the resonating lengths l. Plot $1/l$ vs n, taking n along x-axis and $1/l$ along y-axis, starting from zero on both axes. See whether a straight line can be drawn from the origin to lie evenly between the plotted points.

RESULT

Check if the product nl is found to be constant and the graph of $1/l$ vs n is also a straight line. Therefore, for a given tension, the resonant length l of a given stretched string varies as reciprocal of the frequency.

(ii) Variation of resonant length with tension for constant frequency

PROCEDURE

1. Select a tuning fork of known frequency (say 256 Hz) and hang a load of 1kg from the hanger. Find the resonant length as before.
2. Increase the load on the hanger in steps of 0.5 kg and each time find the resonating length with the same tuning fork. Do it for at least four loads.
3. Record your observations.
4. Plot graph between l^2 and T.

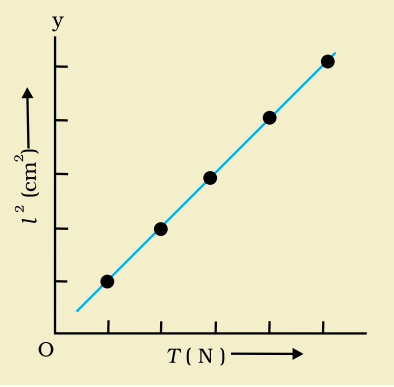


Fig. E 13.4: *Graph between l^2 and T*

OBSERVATIONS (B)

Frequency of the tuning fork = ... Hz

Table E 13.2: Variation of resonant length with tension

Tension applied T (including weight of the hanger) (N)					
Resonating length l of the wire (cm)					
l^2 (cm^2)					
T/l^2 (N cm^{-2})					

CALCULATIONS AND GRAPH

Calculate the value of T/l^2 for the tension applied in each case. Alternatively, plot a graph of l^2 vs T taking l^2 along y-axis and T along the x-axis.

RESULT

It is found that value of T/l^2 is constant within experimental error. The graph of l^2 vs T is found to be a straight line (Fig. E 13.4). This shows that $l^2 \propto T$ or $l \propto \sqrt{T}$.

Thus, the resonating length varies as square root of tension for a given frequency of vibration of a stretched string.

PRECAUTIONS

1. Pulley should be frictionless ideally. In practice friction at the pulley should be minimised by applying grease or oil on it.
2. Wire should be free from kinks and of uniform cross section. If there are kinks, they should be removed by stretching as far as possible.
3. Wedges should be perpendicular to the wire so that a node is formed at the wedge.
4. Tuning fork should be vibrated by striking its prongs against a soft rubber pad.
5. Load should be removed after the experiment.

SOURCES OF ERROR

1. Pulley may not be frictionless.
2. Wire may not be rigid and of uniform cross section.
3. Wedges may not be sharp.

EXPERIMENT 14

AIM

To determine the speed of sound in air at room temperature using a resonance tube.

APPARATUS AND MATERIAL REQUIRED

Resonance tube assembly (improvised), a tuning fork of known frequency (preferably of 512 Hz), a rubber pad, a thermometer, two laboratory stands with clamps and water.

FORMULA USED

The speed of sound in air at room temperature would be $v = 2\nu(l_2 - l_1)$.

Where l_1 is length of air column at first resonance and l_2 is the length of air column at second resonance. ν is the frequency of the tuning fork.

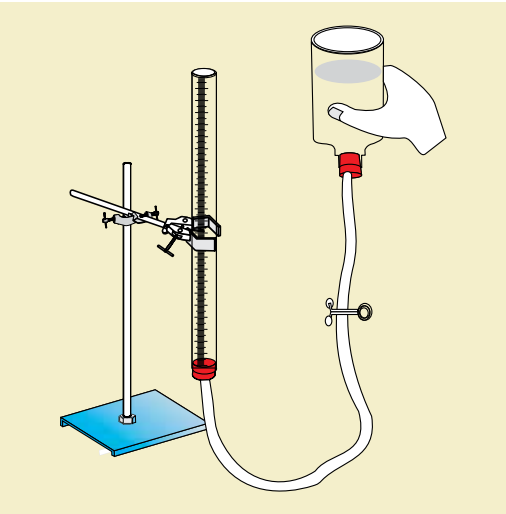


Fig.E 14.1: *Resonance tube assembly*

PROCEDURE

Setting up of improvised resonance tube

1. To set up the improvised resonance tube, following materials have been provided in the kit:
   (a) A 60 cm long tube of diameter about 5 cm with a centimetre scale fixed on it to be used as a resonance tube.
   (b) A plastic bottle without its bottom to be used as a reservoir.

(c) A plastic tube (about 1m long) with rubber stoppers fixed at its two ends. One of the rubber stoppers is to be filled into tube while the other is to be fixed at the mouth of the plastic tube.

(d) Two laboratory stands with clamps to fix the tube and the bottle.

2. Fix the rubber stopper at that end of the resonance tube where the scale reads 60 cm. Fix the other stopper to the mouth of the plastic bottle (reservoir).
3. Fix the resonance tube vertically using a laboratory stand. Similarly, fix the reservoir vertically using another laboratory stand. Take care that the reservoir is fixed with its open end at the highest point of the laboratory stand. Ensure that the resonance tube and the reservoir are vertical (Fig. E 14.1).
4. Note the room temperature with a thermometer. Also, note the frequency ν of the given tuning fork.

Determination of First Resonance Position

5. Fill the water in the reservoir such that the level of water in the resonance tube reaches up to its open end. Make sure that there is no leakage of water from the resonance tube and the reservoir.
6. Close the pinch cock and lower down the position of reservoir on the vertical rod.
7. Gently strike the given tuning fork on a rubber pad and put it nearly 1 cm above the open end of the resonance tube. Keep both the prongs of the tuning fork parallel to the ground and lying one above the other so that the prongs vibrate in the vertical plane. Try to listen the sound being produced in the tube. It may not be audible in this position.
8. Slowly loosen the pinch cock to let the water level fall in the resonance tube very slowly. Keep bringing the tuning fork near the open end of the resonance tube, notice the increasing loudness of the sound.
9. Repeat Steps 7 and 8 till you get the exact position of water level in the tube for which the intensity of sound being produced in the tube is maximum. This corresponds to the first resonance position or fundamental note, if the length of air column is minimum. Close the pinch cock at this position and note the position of water level or length l_1 of air column in the tube. This is the determination of first resonance position while the level of water is falling in the tube.
10. Repeat Steps 5 to 9 to confirm the first resonance position.

11. Next find out the first resonance position by gradually raising the level of water in resonance tube, and holding the vibrating tuning fork continuously on top of its open end. Fix the tube at the position where the sound of maximum intensity is heard.

Determination of Second Resonance Position

12. Lower the position of the water level further in the resonance tube by sliding down the position of reservoir on the vertical stand and opening the pinch cock till the length of air column in the tube increases about three times of the length l_1.
13. Find out the second resonance position and determine the length of air column l_2 in the resonance tube with the same tuning fork and confirm the length l_2 by taking four readings, two when the level of water is falling and the other two when the level of water is rising in the tube.
14. Calculate the velocity of sound.

OBSERVATIONS

1. Temperature of the room θ = ... °C
2. Frequency of tuning fork, ν = ... Hz

Table E 14.1: Determination of length of the resonant air columns

Frequency of tuning fork used (Hz)	S. No.	Length l_1 for the first resonance position of the tube			Length l_2 for the second resonance position of the tube		
		Water level falling	Water level rising	Mean length l_1 (cm)	Water level falling	Water level rising	Mean length l_2 (cm)
	1.						
	2.						

CALCULATIONS

(i) Frequency of tuning fork ν = ... Hz

Speed of sound in air $v = 2\,\nu\,(l_2 - l_1)$ = ... ms^{-1}

RESULT

The velocity of sound v in air at room temperature is ..... ms^{-1}.

PRECAUTIONS

1. The resonance tube should be kept vertical using the levelling screws.
2. The experiment should be performed in a quiet atmosphere so that the resonance positions may be identified properly.
3. Striking of tuning fork on rubber pad must be done very gently.
4. The lowering and raising of water level in the resonance tube should be done very slowly.
5. The choice of frequency of the tuning forks being used should be such that the two resonance positions may be achieved in the air column of the given resonance tube.
6. The vibrating tuning fork must be kept about 1 cm above the top of the resonance tube. In any case it should not touch the resonance tube.

EXPERIMENT 15

AIM

To determine the specific heat capacity of a given (i) solid and (ii) liquid by the method of mixtures.

APPARATUS AND MATERIAL REQUIRED

Copper calorimeter with lid, stirrer and insulating cover, two thermometers (0 °C to 110 °C, with a least count of 0.5 °C), a solid (pendulum bob), given liquid, two beakers (100 mL and 250 mL), a heating device (heater/hot plate/gas burner); physical balance with weight box (including fractional weights or spring balance), a piece of strong non-flexible thread (25–30 cm long), water, laboratory stand, tripod stand and wire gauze.

PRINCIPLE

For a body of mass m and specific heat capacity s, the amount of heat Q lost/gained by it when its temperature falls/rises is given by

$$\Delta Q = ms\Delta t \qquad \text{(E 15.1)}$$

Specific heat capacity: It is the amount of heat required to raise the temperature of unit mass of a substance through 1°C. Its S.I. unit is $Jkg^{-1}K^{-1}$.

Principle of Calorimetry: If bodies of different temperatures are brought in thermal contact, at thermal equilibrium the amount of heat lost by the body at higher temperature is equal to the amount of heat gained by the body at lower temperature, provided no heat is lost to the surrounding.

(i) Specific heat capacity of given solid by method of mixtures

PROCEDURE

1. Set the physical balance and make sure that all initial adjustments are made.

2. Weigh the empty calorimeter with stirrer and lid with the physical balance/spring balance. Ensure that calorimeter is clean and dry. Note the mass m_1 of the calorimeter with stirrer. Pour some water in the calorimeter. Make sure that the quantity of water taken is sufficient to completely submerge the given solid in it. Weigh the calorimeter with water along with the stirrer and note its mass m_2. Place the calorimeter in its insulating cover.
3. Dip the solid in water and take it out. Now shake it to remove water sticking to its surface. Weigh the wet solid with the physical balance and note down its mass m_3.
4. Tie the solid tightly with the thread. Make sure that it can be lifted by holding the thread without slipping.

   Place a 250 mL beaker on the wire gauze kept on a tripod stand as shown in the Fig E 15.1(a). Fill the beaker up to the half with water. Now suspend the solid in the beaker containing water by tying the other end of the thread to a laboratory stand. The solid should be completely submerged in water and should be atleast 0.5 cm below its surface. Now heat the water with the solid suspended in it [Fig. E 15.1 (a)].

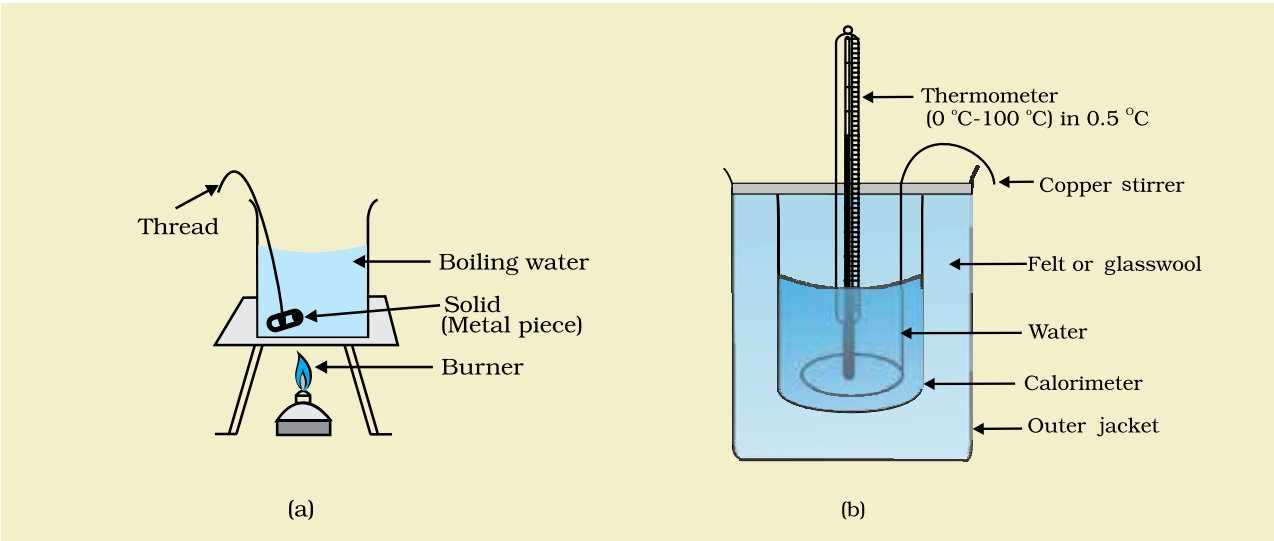


Fig. E 15.1 (a),(b): *Experimental setup for determining specific heat of a given solid*

5. Note the least count of the thermometer. Measure the temperature of the water taken in the calorimeter. Record the temperature t_1 of the water.
6. Let the water in the beaker boil for about 5–10 minutes. Now measure the temperature t_2 of the water with the other thermometer and record the same. Holding the solid with the thread tied to it, remove it from the boiling water, shake it to remove water sticking on it and quickly put it in the water in the

calorimeter and replace the lid immediately (Fig. E 15.1(b)). Stir the water with the stirrer. Measure the temperature of the water once equilibrium is attained, that is, temperature of the mixture becomes constant. Record this temperature as t_3.

OBSERVATIONS

Mass of the empty calorimeter with stirrer (m_1) = ... g

Mass of the calorimeter with water (m_2) = ... g

Mass of solid (m_3) = ... g

Initial temperature of the water (t_1) = ... °C = ... K

Temperature of the solid in boiling water (t_2) = ... °C = ... K

Temperature of the mixture (t_3) = ... °C

Specific heat capacity of material of calorimeter s_1 (given) = ... $Jkg^{-1}\,°C^{-1}$($Jkg^{-1}K^{-1}$)

Specific heat capacity of water (s)(given) = ... $Jkg^{-1}\,°C^{-1}$ = ... $Jkg^{-1}\,K^{-1}$

CALCULATIONS

1. Mass of the water in calorimeter ($m_2 - m_1$) = ... g = ... kg
2. Change in temperature of water and calorimeter ($t_3 - t_1$) = ... °C =... K
3. Change in temperature of solid ($t_2 - t_3$) = ... °C=... K

   Heat given by solid in cooling from t_2 to t_3

   = Heat gained by liquid in raising its temperature from t_1 to t_3 + heat gained by calorimeter in raising its temperature from t_1 to t_3.

   $m_3 s_0 (t_2 - t_3) = (m_2 - m_1) s (t_2 - t_1) + m_1 s_1 (t_3 - t_1)$

   where s_0 is the specific heat capacity of given solid

$$S_o = \frac{(m_2 - m_1)s(t_2 - t_1) + m_1 s_1 (t_3 - t_1)}{m_3 (t_2 - t_3)} = ...Jkg^{-1}k^{-1}$$

(ii) Specific heat capacity of given liquid by method of mixtures

PROCEDURE

1. Set the phyiscal balance and make sure that all initial adjustments are made.
2. Weigh the empty calorimeter with stirrer and lid with the physical balance/spring balance. Ensure that calorimeter is clean and dry. Note the mass m_1 of the calorimeter. Pour the given liquid in the calorimeter. Make sure that the quantity of liquid taken is sufficient to completely submerge the solid in it. Weigh the calorimeter with liquid along with the stirrer and the lid and note its mass m_2. Place the calorimeter in its insulating cover.
3. Take a solid whose specific heat capacity, is known. Dip it in water in a container and shake it to remove the water sticking to its surface. Weigh the wet solid with the physical balance and note down its mass m_3.
4. Tie the solid tightly with the thread at its middle. Make sure that it can be lifted by holding the thread without slipping.

   Place a 250 mL beaker on the wire gauze kept on a tripod stand as shown in Fig. E 15.1(a). Fill the beaker up to half with water. Now suspend the solid in the beaker containing water by tying the other end of the thread to a laboratory stand. The solid should be completely submerged in water and should be atleast 0.5 cm below the surface. Now heat the water with the solid suspended in it [Fig. E 15.1(a)].
5. Note the least count of the thermometer. Measure the temperature taken in the calorimeter and record its temperature t_1.
6. Let the water in the beaker boil for about 5–10 minutes. Now measure the temperature t_2 of the liquid in calorimeter with the other thermometer and record the same. Holding the solid with the thread tied to it remove it from the boiling water, shake it to remove water sticking on it and quickly put it in the liquid in the calorimeter and replace the lid immediately [Fig. E 15.1(b)]. Stir it with the stirrer. Measure the temperature of the mixture once equilibrium is attained, that is, temperature of the mixture becomes constant. Record this temperature as t_3.

OBSERVATIONS

Mass of the empty calorimeter with stirrer (m_1) = ... g

Mass of the calorimeter with liquid (m_2) = ... g

Mass of solid (m_3) = ... g

Initial temperature of the liquid (t_1) = °C = ... K

Temperature of the solid in boiling water (t_2) = °C = ... K

Temperature of the mixture (t_3) = °C = ... K

Specific heat capacity of material of calorimeter s_1 (given)
= ... Jkg^{-1} $°C^{-1}$ (Jkg^{-1} K^{-1})

Specific heat capacity of soild (s_0) (given) = ... Jkg^{-1} K^{-1}

CALCULATIONS

1. Mass of the liquid in calorimeter ($m_2 - m_1$) = ... g = ... kg
2. Change in the temperature of liquid and calorimeter ($t_3 - t_1$) = ... °C
3. Change in the temperature of solid ($t_2 - t_3$) = ... °C

   Heat given by solid in cooling from t_2 to t_3.

   = Heat gained by liquid in raising its temperature from t_1 to t_3 + heat gained by calorimeter in raising its temperature from t_1 to t_3.

   $m_3 s_0 (t_2 - t_3) = (m_2 - m_1) s (t_2 - t_1) + m_1 s_1 (t_3 - t_1)$

   where s is the specific heat capacity of given liquid.

$$s = \frac{m_3 s_o (t_2 - t_3) - m_1 s_1 (t_3 - t_1)}{(m_2 - m_1)(t_2 - t_1)} = ... Jkg^{-1}k^{-1}$$

RESULT

1. The specific heat capacity of the given solid is ... Jkg^{-1} K^{-1} within experimental error.
2. The specific heat capacity of the given liquid is ... Jkg^{-1} K^{-1} within experimental error.

PRECAUTIONS

1. Physical balance should be in proper working condition and ensure that there is no zero error.
2. The two thermometers used should be of the same range and least count.
3. The solid used should not be soluble or chemically reactive with the liquid or water used. The density of solid should be more than that of the given liquid and water.
4. The calorimeter should always be kept in its insulated cover and at a sufficient distance from the source of heat and should not be exposed to sunlight so that it absorbs no heat from the surrounding.
5. The solid should be transferred quickly so that its temperature is same as recorded when it is dropped in the liquid.
6. Liquid should not be allowed to splash while dropping the solid in it in the calorimeter. It is advised that the solid should be lowered gently into the liquid with the help of the thread tied to it.
7. While measuring the temperature, the thermometers should always be held in vertical position. The line of sight should be perpendicular to the mercury level while recording the temperature.

ACTIVITY 1

AIM

To make a paper scale of given least count: (i) 0.2 cm and (ii) 0.5 cm, and to use these scales to measure length of a given object.

APPARATUS AND MATERIAL REQUIRED

White paper sheet, pencil, sharpener, eraser, metre scale (ruler) and fine tipped black ink or gel pen.

PROCEDURE

(i) Making Paper Scale of Least Count 0.2 cm

1. Fold a sheet of white paper in the middle along its length.
2. Using a sharp pencil, draw a line AB of length 30 cm in either half of the white paper sheet [Fig. A1.1(a)].
3. Starting with the left end marked A as zero, mark very small dots on the line AB after every 1.0 cm and write 0,1,2 ..., 30 at successive dots.
4. Draw thin, sharp straight lines, each 5 cm in length, perpendicular to the line AB at the position of each dot mark.
5. Draw 5 thin, sharp lines parallel to the line AB at distances of 1.0 cm, 2.0 cm, 3.0 cm, 4.0 cm and 5.0 cm respectively. Let the line at 5 cm be DC while those at 1 cm, 2 cm, 3 cm, and 4 cm be A_1B_1, A_2B_2, A_3B_3 and A_4B_4 respectively [Fig A 1.1(a)].

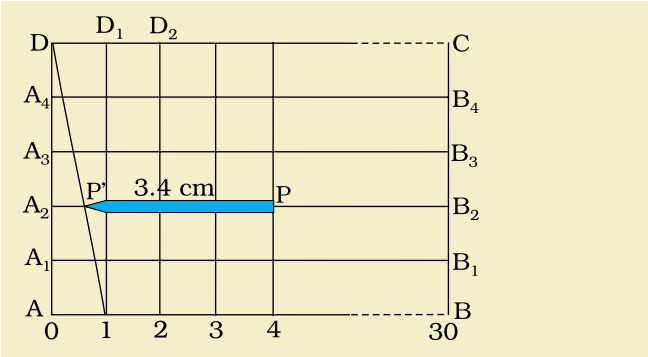


Fig. A 1.1 (a): *Making a paper scale of least count 0.2 cm*

6. Join point D with the dot at 1 cm on line AB. Intersection of this line with lines parallel to AB at A_4, A_3, A_2 and A_1 are respectively 0.2 cm, 0.4 cm, 0.6 cm and 0.8 cm in length.
7. Use this arrangement to measure length of a pencil or a knitting needle with least count of 0.2 cm.

(ii) Making Paper Scale of Least Count 0.5 cm

1. Using a sharp pencil, draw a line AB of length 30 cm in the other half of the white paper sheet [Fig. A 1.1(b)].

2. Repeat Steps 3 to 6 as in the above Activity, but draw only two lines parallel to AB at distances of 1.0 cm and 2.0 cm instead of 5 cm.

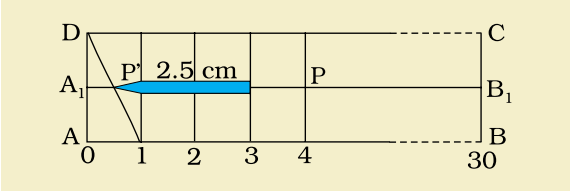


Fig. A 1.1(b)

3. Join diagonal 1–D by fine-tipped black ink pen [Fig. A 1.1 (b)].

4. Use this scale to measure length of a pencil/knitting needle with least count of 0.5 cm. Fractional part of length 0.5 cm is measured on line A_1B_1.

(iii) Measuring the Length of a Pencil Using the Paper Scales A and B

1. Place the pencil PP' along the length of the paper scale A (least count 0.2 cm) such that its end P is on a full mark (say 1.0 cm or 2.0 cm etc. mark). The position of the other end P′ is on diagonal 1–D. If P′ goes beyond the diagonal, place it on next upper line, in which fraction of intersection is 0.2 cm larger, and so on. Thus, in Fig. A 1.1 (a), length of the pencil = 3cm+0.2×2 cm=3.4 cm. Take care that you take the reading with one eye closed and the other eye directly over the required graduation mark. The reading is likely to be incorrect if the eye is inclined to the graduation mark.
2. Repeat preceding Step 1, using the paper scale B having least count 0.5 cm and record your observations in proper units.

OBSERVATIONS

Least count of the paper scale A = 0.2 cm
Least count of the paper scale B = 0.5 cm

RESULT

1. Scale of least count 0.2 cm and 0.5 cm have been made; and
2. Length of pencil as measured by using the scales made above is (a) ... cm and (b) ... cm.

PRECAUTIONS

1. Very sharp pencil should be used.
2. Scale should be cut along the boundary by using a sharp paper cutter.
3. Observation should be recorded showing accuracy of the scale.
4. While measuring lengths, full cm mark should be made to coincide with one end of the object and other end should be read on the scale.

ACTIVITY 2

AIM

To determine the mass of a given body using a metre scale by the principle of moments.

APPARATUS AND MATERIAL REQUIRED

A wooden metre scale of uniform thickness (a wooden strip of one metre length having uniform thickness and width can also be used); load of unknown mass, wooden or metal wedge with sharp edge, weight box, thread (nearly 30 cm long), a spirit level, and a raised platform of about 20 cm height (such as a wooden or metal block).

PRINCIPLE

For a body in equilibrium, which is free to rotate about a fixed axis, the sum of the clockwise moments is equal to the sum of the anticlockwise moments.

If M_1 is the known mass, suspended at a distance l_1 on one side from the centre of gravity of a beam and M_2 is the unknown mass, suspended at a distance l_2 on the other side from the centre of gravity, and the beam is in equilibrium, then $M_2\ l_2 = M_1\ l_1$.

PROCEDURE

1. Make a raised platform on a table. One can use a wooden or a metal block or a pile of books. However, the platform should be sturdy. Place a wedge having a sharp edge on it.

2. Make two loops of thread to be used for suspending the unknown mass and the weights from the metre scale (beam). Insert the loops at about 10 cm from the edge of the metre scale from both sides.

3. Place the metre scale with thread loops on the wedge and adjust it till it is balanced. Mark two points on the scale above the wedge where the scale is balanced. Join these two points with a straight line which would facilitate to pin point the location of

balance position even if the scale topples over from the wedge due to some reason. This line is passing through the centre of gravity of scale.

4. Take the unknown mass in one hand. Select a weight from the weight box which feels nearly equal to the unknown mass when it is held in the other hand.

5. Suspend the unknown mass from either of the two loops of thread attached to the metre scale. Suspend the known weight from the other loop (Fig. A 2.1).

6. Adjust the position of the known weight by moving the loop till the metre scale gets balanced on the sharp wedge. Make sure that in balanced position the line drawn in Step 3 is exactly above the wedge and also that the thread of two loops passing over the scale is parallel to this line.

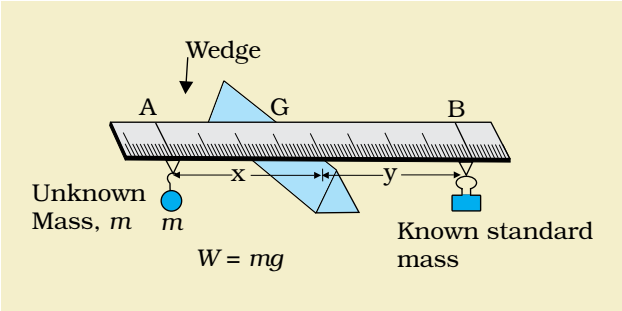


Fig. A 2.1: *Experimental set up for determination of mass of a given body*

7. Measure the distance of the position of the loops from the line drawn in Step 3. Record your observations in table 2.1.

8. Repeat the activity atleast two times with a slightly lighter and a heavier weight. Note the distances of unknown mass and weight from line drawn in Step 3 in each case.

OBSERVATIONS

Position of centre of gravity = ... cm

Table A 2.1: Determination of mass of unknown object

S. No.	Mass M_1 suspended from the thread loop to balance the metre scale (*g*)	Distance of the mass from the wedge l_1 (*cm*)	Distance of solid of unknown mass from the wedge l_2 (*cm*)	Mass of unknown load $M_2 = \frac{M_1 l_1}{l_2}$ (*g*)	Average mass of unknown load (*g*)
1.					
2.					
3.					
4.					
5.					

CALCULATIONS

In balanced position of the metre scale, moment of the force on one side of the wedge will be equal to the moment of the force on the other side.

Moment of the force due to known weight = $(M_1 l_1)$ g

where g is the acceleration due to gravity.

Moment of the force due to unknown weight = $(M_2 l_2)$ g

In balanced position,

$$(M_1 l_1)\, g = (M_2 l_2)\, g$$

or $$M_2 = (M_1 l_1)/l_2$$

Average mass of unknown load = ... g

RESULT

Mass of the given body = ... g (within the experimental error)

PRECAUTIONS

1. Wedge should be sharp and always perpendicular to the length of the scale.
2. Thread loops should be perpendicular to the length of the scale.
3. Thread used for loops should be thin, light and strong.
4. Air currents should be minimised.

ACTIVITY 3

AIM

To plot a graph for a given set of data choosing proper scale and show error bars due to the precision of the instruments.

APPARATUS AND MATERIAL REQUIRED

Graph paper, a pencil, a scale and a set of data.

PRINCIPLE

Any measurement using a device has an uncertainty in its value depending on the precision of the device used. For example, in the measurement of diameter of a spherical bob, the correct way is to represent it $d \pm \Delta d$, where Δd is the uncertainty in measurement of d given by the least count of the vernier/screw gauze used. Representation of $d \pm \Delta d$ in a graph is shown as a line having a length of $\pm \Delta d$ about point 'd'. This is known as the error bar of d.

Here, we consider the uncertainty in measurements only due to the least count of the measuring instrument so as to learn how uncertainty for a given data is shown in a line graph.

Let us take the example of the graph between time period T, and the length l, of a simple pendulum. The uncertainty in measurement of time period will depend on the least count of the stopwatch/clock, while that the measurement of length of the pendulum will depend on the least count of the device(s) used to measure length. Table A 3.1 gives the data for the time period of simple pendulum measured in an experiment along with the uncertainty in the measurement of the length and time period of the pendulum.

PLOTTING OF A GRAPH WITH ERROR BARS

Steps involved in drawing a graph with error bars on it are as follows:

1. Draw x and y axes on a graph sheet and select an appropriate scale for plotting of the graph. In order to show uncertainty/error in given data, it is advisable that the scale chosen should be such that the lowest value of uncertainty/error on either axis could be shown by at least the smallest division on the graph sheet.

Table A 3.1 Time period of simple pendulums of different lengths

S.No.	Length of the Pendulum		Time Period		
	Length as measured with metre scale, L (cm)	Length with uncertainty in L (least count of scale 0.1 cm) (cm)	Average time period as measured with stopwatch, T (s)	Time period with uncertainty in T (least count of stopwatch 0.1 s) (s)	Square of time period T^2 with uncertainty
1.	80.0	80 ± 0.1	1.8	1.8 ± 0.1	3.24 ± 0.2
2.	90.0	90 ± 0.1	1.9	1.9 ± 0.1	3.61± 0.2
3.	100.0	100 ± 0.1	2.0	2.0 ± 0.1	4.0 ± 0.2
4.	110.0	110 ± 0.1	2.1	2.1 ± 0.1	4.4 ± 0.2
5.	120.0	120 ± 0.1	2.2	2.2 ± 0.1	4.84 ± 0.2
6.	130.0	130 ± 0.1	2.3	2.3 ± 0.1	5.29 ± 0.2
7.	140.0	140 ± 0.1	2.4	2.4 ± 0.1	5.76 ± 0.2
8.	150.0	150 ± 0.1	2.4	2.4 ± 0.1	5.76 ± 0.2

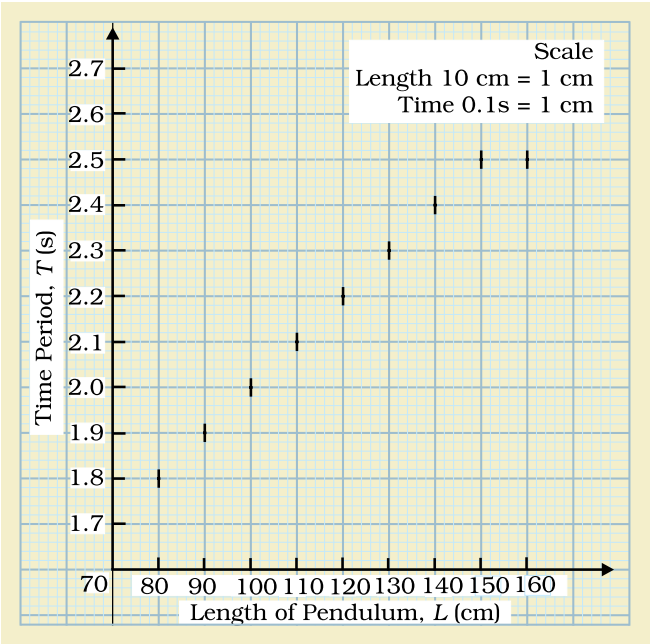


Fig. A 3.1: *Error bars corresponding to uncertainty in time period of the given pendulum (uncertainty in length is not shown due to limitation of scale)*

2. Mark the points on the graph for each pair of data without taking into account the given uncertainty/error.

3. Each point marked on the graph in Step 2 has an uncertainty in the value shown on either the *x*-axis or the *y*-axis or both. For example, let us consider the case for the point corresponding to (80, 1.8) marked on the graph. If we take into account the uncertainty in measurement of length in this case, the actual length of the pendulum may lie between 79.9 cm and 80.1 cm. This uncertainty in the data is shown in the graph by a line of length 0.2 cm (in accordance with the scale chosen) drawn parallel to *x*-axis with its midpoint at 80.0 cm. This line shows the error bar for the pendulum of length 80.0 cm. One can similarly draw error bar for each length of the pendulum.

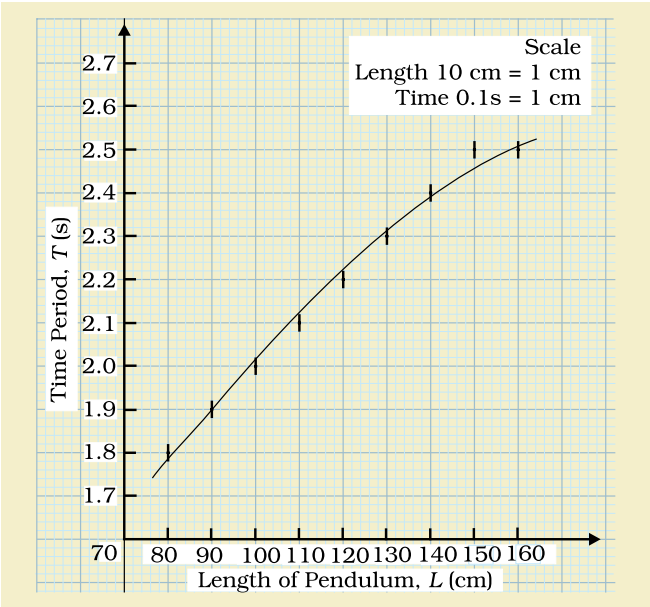


Fig. A 3.2: *Graph showing variation in time period of a simple pendulum with its length along with error bars*

4. Repeat the procedure explained in Step 3 to draw the error bars for uncertainty the in measurement of time period. However, the error bars in this case will be parallel to the y-axis.

5. Once the error bars showing the uncertainty for data in both the axes of the graph have been marked, each pair of data on the graph will be marked with a + or - sign, depending on the extent of uncertainty and the scale chosen for each axis, instead of a point usually marked for drawing line graph (Fig. A 3.1).

6. A smooth curve drawn passing as close as possible through all the + marks marked on the graph, instead of points, gives us the plot between the two given variables (Fig. A 3.2).

RESULT

A given set of data gives unique points. However, when plotted, a curve representing that data may not physically pass through these points. It must, however, pass through the area enclosed by the error bars around each point.

PRECAUTIONS

1. Normally the point of intersection of the two axes, x-axis and y-axis, represnt the origin O at (0,0). However, this is not always necessory to take the value of physical quatities being plotted as zero at the intersection of the x-axis and y-axis. For a given set of data, try to maximize the use of the graph paper area.

2. While deciding on scale for plotting the graph, efforts should be made to choose a scale which would enable to depict uncertainty by at least one smallest division in the graph sheet.

3. While joining the data points on the graph sheet, enough care should be taken to join them smoothly. The curve or line should be thin.

4. Every graph must be given a suitable heading, which should be written on top of the graph.

ACTIVITY 4

AIM

To measure the force of limiting rolling friction for a roller (wooden block) on a horizontal plane.

APPARATUS AND MATERIAL REQUIRED

Wooden block with a hook on one side, set of weights, horizontal plane fitted with a frictionless pulley at one end, pan, spring balance, thread, spirit level, weight box and 10–11 cylindrical pencils to be used as rollers.

PRINCIPLE

Rolling friction is the least force required to make a body start rolling over a surface. Rolling friction is less than the sliding friction.

PROCEDURE

1. Check that the pulley is almost frictionless otherwise oil it to reduce friction.
2. Check the horizontal surface with a spirit level and place a few cylindrical pencils parallel to each other as shown in Fig. A 4.1. The pencils are to be used as rollers.

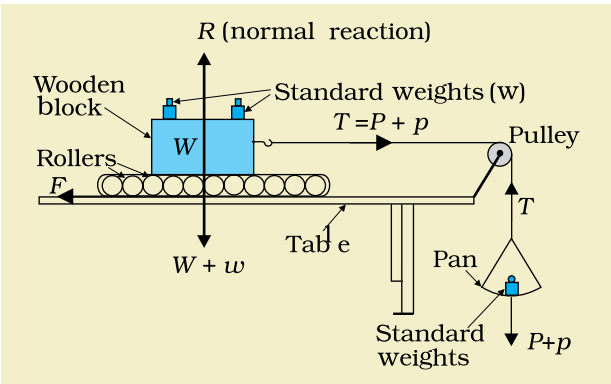


Fig. A 4.1: *A setup to study the rolling friction*

3. Weigh the wooden block.
4. Find the weight of the pan P. Tie one end of the thread to the pan and let it pass over the pulley.
5. Now put the block over the arrangement of pencils and tie the other end of the thread to its hook.

6. Put a small weight in the pan and observe whether the wooden block kept on rollers begin to move.
7. If the block does not start moving, put some more weight on the pan from the weight box and keep increasing weights in the pan gradually till the block just begins to move on rollers. Let mass placed on pan be p.
8. Note the total weight on the pan, including the weight of the pan and record them in Table A 4.1.
9. Put a 100 g weight over the wooden block and repeat Steps (7) to (9).
10. Increase the weights in steps on the wooden block and repeat Steps (7) to (9).

OBSERVATIONS

Mass of the wooden block m = ... g = ... kg

Weight of the wooden block, W (mg) = ... N

Weight applied through the pan

= (Mass of the pan + mass placed on it) × acceleration due to gravity (g)

= ... N

Table A 4.1: Table for additional weights

S. No.	Mass of standard weights on wooden block, *w* (kg)	Total weight being pulled = $(W + w) \times g$ = Normal Reaction, *R* (N)	Total weight being pulled = $(W + w) \times g$ = Normal Reaction, *R* (N)	Total weight (force) pulling the block and standard weights $(P+p)$ g = *Limiting friction (N)*
1.				
2.				
3.				
4.				

RESULT

As the total weight that is being pulled is increased limiting value of rolling friction also increases.

PRECAUTIONS

1. The pulley should be frictionless. It should be lubricated, if necessary.
2. The portion of the string between the pulley and the hook should be horizontal.
3. The surfaces of the pencils as well as the plane and the block should be clean, dry and smooth.
4. The weights in the pan should be placed carefully and very gently.

ACTIVITY 5

AIM

To study the variation in the range of a jet of water with the change in the angle of projection.

APPARATUS AND MATERIAL REQUIRED

PVC or rubber pipe, a nozzle, source of water under pressure (i.e., a tap connected to an overhead water tank or water supply line), a measuring tape and a large size protractor.

PROCEDURE

1. **Making a large protractor:** Take a circular plyboard or thick circular cardboard sheet of radius about 25 cm. Draw a diameter through its centre. Cut it along with the diameter to form two D's. On one of the dees, draw angles at an interval of 15° starting from 0°.

2. Attach one end of pipe to a tap. At the other end of the pipe fix a nozzle to obtain a jet of water. Ensure that there is no leakage in the pipe.

3. Fix the graduated D vertically on the ground with its graduated–face towards you, as shown in Fig. A 5.1.

4. Place the nozzle at the centre O of the protractor and direct the nozzle along θ =15° mark.

5. Open the tap to obtain a jet of water. Ensure that water leaves the nozzle at an angle of 15° from the horizontal and also the ground in front is in level with point O and horizontal. The water coming out of the jet would strike the ground after completing its parabolic trajectory. Ask your friend to mark the point (A) where the water falls. Close the tap.

6. Measure the distance between point O and A. This gives the range R corresponding to the angle of projection, 15°.

7. Now, vary θ_0 in steps of 15° up to 75° and measure the corresponding range for each angle of projection.

8. Plot a graph between the angle of projection θ_0 and range R (Fig. A 5.2).

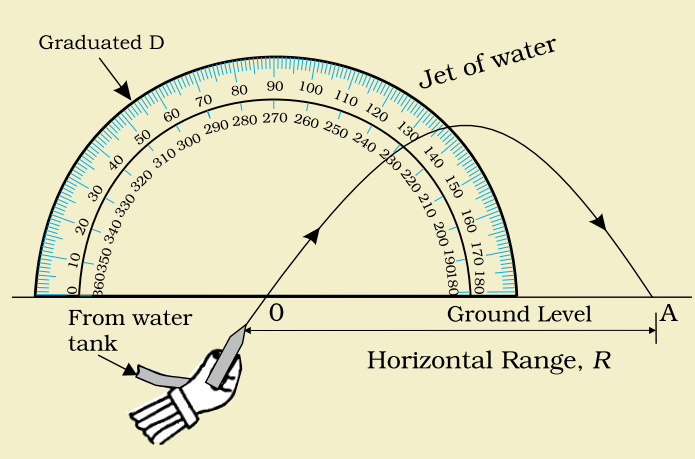


Fig. A 5.1: *Setup for studying the variation in the range of a jet of water with the angle of projection*

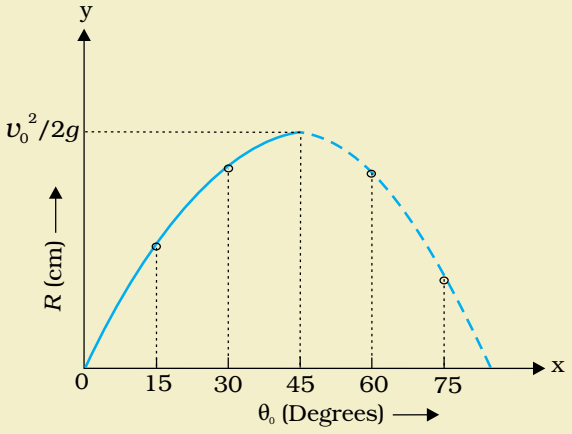


Fig. A 5.2: *Variation of range with angle of projection*

OBSERVATIONS

Least count of measuring tape = ... cm

Table A 5.1: Measurement of range of water jet

S. No.	Angle of projection θ_0	Range *R* (cm)
1.	15°	
2.	30°	
3.	45°	
4.	60°	
5.	75°	

GRAPH

Plot a graph between angle of projection (on *x*-axis) and range (on *y*-axis).

RESULT

1. The range of jet of water varies with the angle of projection as shown in Fig. A 5. 2.
2. The range of jet of water is maximum when θ_0 = ...°

PRECAUTIONS

1. There should not be any leakage in the pipe and the pressure with which water is released from the jet should not vary during the experiment.
2. The jet of water does not strike the ground at a point but gets spread over a small area. The centre of this area should be considered for measurement of the range.
3. The nozzle should be small so as to get a thin stream of water.

ACTIVITY 6

AIM

To study the conservation of energy of a ball rolling down an inclined plane (using a curved channel or a transparent flexible tube).

APPARATUS AND MATERIAL REQUIRED

A curved channel (radius of curvature 30–35 cm, length 65 cm) made of a strong metal, or transparent flexible tube, a steel ball of about 1.5 cm diameter, spirit level, tissue paper or cotton, laboratory stand, clamp and a half metre scale.

PRINCIPLE

The law of conservation of energy states that 'energy can neither be created nor destroyed but can only be changed from one form to another'.

For a mechanical system, *viz.*, the rolling of a steel ball on a perfectly smooth channel, the energy of ball remains in the form of its kinetic and potential energies and during the course of motion, a continuous

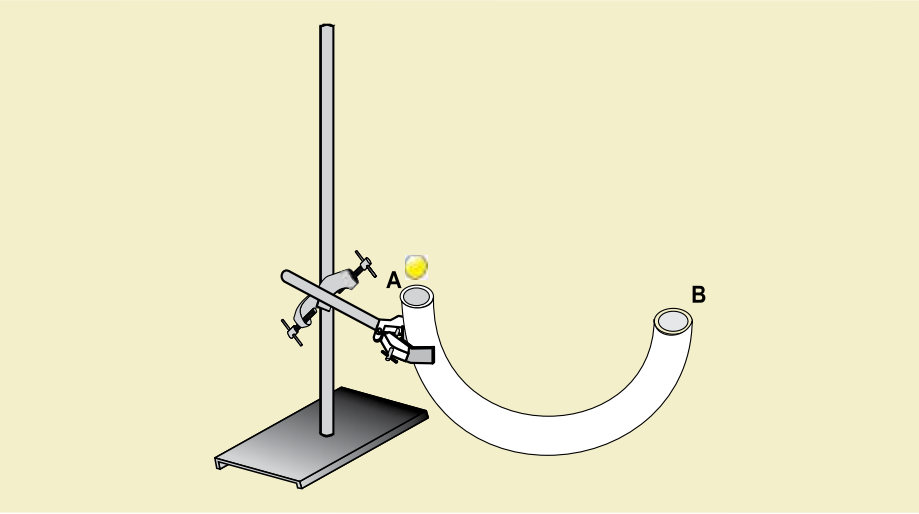


Fig.A 6.1: *Set up for studying the conservation of energy using transparent flexible tube*

transformation between these energies takes place. The sum of its kinetic and potential energies remains constant provided there is no dissipation of energy due to air resistance, friction etc.

In this experiment, the law of conservation of energy is illustrated by the motion of a steel ball rolling in a transparent flexible tube. When the ball is released from point A on one end of the tube, it will roll down inside the tube and go up on the opposite side to point B, about the same height h from which it was released. If the radius of the curved tube on right hand side is changed, the ball will still move till it reaches the same vertical height from which it was released.

At point A, the steel ball possesses only potential energy and zero kinetic energy. The potential energy transforms into kinetic energy when it settles down to the bottom of the tube (Q). As the ball starts rolling up towards point B, the kinetic energy is converted back into potential energy and when the ball stops at point B, it has only potential energy and zero kinetic energy. The law of conservation of mechanical energy can be verified by the equality of two vertical heights AA′ and BB′. Due to the loss of energy against friction, BB′ will always be slightly samller than AA′.

PROCEDURE

1. Adjust the experimental table horizontally with the help of spirit level.
2. Clean the steel ball and the flexible tube with cotton or tissue paper. Even a minute amount of dust or stain on the ball or in the tube can cause much friction.
3. Set the curved tube vertically on a horizontal table with the help of clamp stands.
4. Release the steel ball from point A of the curved tube. Find the vertical height AA′ (h) of the point A from the table using a scale.
5. Note the point B up to which the ball reaches the tube on the other side when the ball was released from point A. Find the vertical height BB′ (h') (Fig. A. 6.1). Record the observations. While observing the highest position of the steel ball on other side, observer has to be very alert as the ball stays at the highest position only for an instant.
6. Repeat the activity for different initial heights of the same tube and note the heighest position to which the steel ball rolls up on other side of the tube in each case. Record the observation in the Table A 6.1.

OBSERVATIONS

Table A 6.1

S. No.	Height of point A on the tube from which the ball is rolled down	Height of point B on the tube up to which the ball rolls up	Difference ($h - h'$) (cm)
	h (cm)	h' (cm)	
1.			
2.			
3.			

RESULT

It is observed that initial vertical height and final vertical height up to which the ball rolls up are approximately same. Thus, the rolling steel ball has same initial and final potential energies, though during the motion, the form of energy changes. The total mechanical energy (sum of kinetic and potential energies) remains same. This is the verification of law of conservation of energy.

PRECAUTIONS

1. Steel balls and the tube must be cleaned properly with cotton/ tissue paper.
2. Both halves of the tube must lie in the same vertical plane.
3. The tube must be stable and should not have any movement due to rolling of the ball or otherwise.
4. The position of the ball at the highest point while climbing up the tube must be noted quickly and carefully.

ACTIVITY 7

AIM

To study the dissipation of energy of a simple pendulum with the time.

APPARATUS AND MATERIAL REQUIRED

A heavy pendulum bob, laboratory stand, split cork, a long fine strong cotton thread (1.5 m to 2m), metre scale, spring balance and a sheet of paper and cotton.

FORMULA USED

$$E_n = \frac{1}{2} k A_n^2$$

and k =mg/L

where, k is the force constant

m is the mass of the bob

L is the length of pendulum

g is the acceleration due to gravity

A_n is the amplitude of oscillation

PROCEDURE

1. Set up a simple pendulum following the steps suggested in Experiment No. 6.
2. Displace the bob to one side, not more than 15 degrees angular displacement, from the vertical position OA and then release it gently. In case you find that the stand shaky, put some heavy object on its base. Make sure that the bob starts oscillating in a vertical plane about its rest (or mean) position OA and does not (i) spin about its own axis, or (ii) move up and down while oscillating, or (iii) revolve in an elliptic path around its mean position.

3. Fix a metre scale just below the pendulum so that it is in the plane of oscillations of the pendulum, such that the zero mark of the scale is just below the bob at rest.
4. When the pendulum oscillates, you have to observe the point on the scale above which the bob rises at its maximum displacement. In doing this, do not worry about millimetre marks. Take observations only up to 0.5 cm.
5. Pull the pendulum bob so that it is above the 15 cm mark. Thus, the initial amplitude will be A_0 = 15 cm at n = 0. Leave the bob gently so that it starts oscillating.
6. Keep counting the number of oscillations when the bob is at its maximum displacement on the same side.
7. Record the amplitude A_n at the end of *n* number of oscillations, for n = 5, 10, 15, ..., that is at the end of every five oscillations. You may even note A_n after every 10 oscillations. Record your observations in Table A 7.1
8. Plot a graph of A^2_n versus *n* and interpret the graph (Fig. A 7.1).
9. Stick a bit of cotton or a small strip of paper to the bob so as to increase the damping, and repeat the experiment.

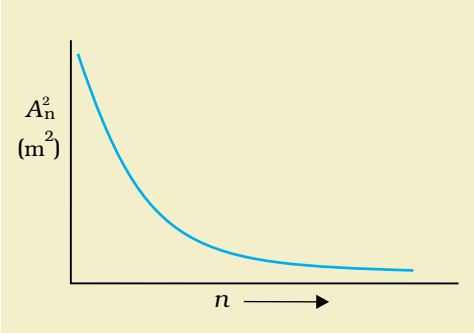


Fig. A 7.1: *Graph between A_n^2 and n for a simple pendulum*

Least count of spring balance = ...g

Least count of meter scale = ...

Mass of bob, m = ...g

Radius of bob, r (given) = ... cm

Length between top of bob and point of suspension l = ... cm

Effective length of bob, L = (l+r) = ... cm

Force constant $k = \frac{mg}{L}$ = ... Nm^{-1}

Initial amplitude of oscillation, A_O = ... cm

Initial energy, $E_o = \frac{1}{2} k A_o^2$ = ... J

Table A 7.1: Decay of amplitude with time and dissipation of energy of simple pendulum

S. No.	Amplitude, A_n (cm)	Number of oscillations, n	A_n^2	Energy of oscillater, E_n (J)	Dissipation of energy, $(E_n - E_o)$ (J)
1.					
2.					
3.					
4.					

RESULT

Since the energy of a pendulum is proportional to the square of its amplitude, we may infer from the graph that energy of a simple pendulum dissipates with time.

PRECAUTIONS

1. The experiment should be performed at a place where air flow is minimum
2. The pendulum must swing for at least a couple of oscillation before recording its amplitude, this will ensure that the pendulum is moving in the same plane.

ACTIVITY 8

AIM

To observe the change of state and plot a cooling curve for molten wax.

APPARATUS AND MATERIAL REQUIRED

A 500 mL metallic jug/mug, tripod stand, wire gauge, clamp stand, hard glass boiling tube, celsius thermometer of least count 0.5 °C, a stopwatch/stop-clock, burner, parraffin wax, cork with a hole to fit the boiling tube and hold a thermometer vertically.

PROCEDURE

1. Note the least count and range of the thermometer.
2. Note the least count of the stop-clock.
3. Record the room temperature.
4. Set up the tripod, burner and heating arrangement as shown in Fig. A 8.1.

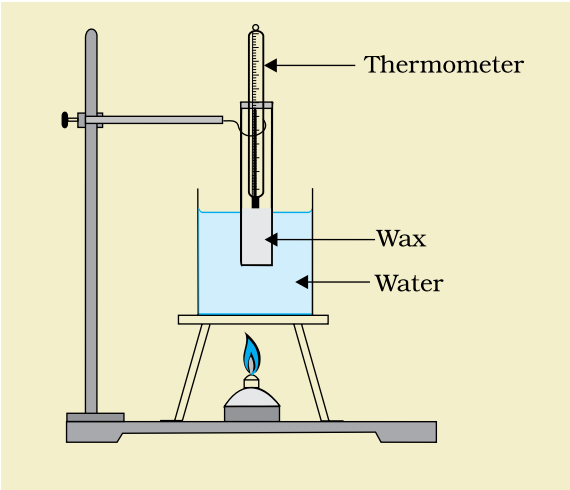


Fig. A 8.1: *Experimental set up*

5. Adjust the boiling tube and the thermometer such that the graduation marks could be visible easily.
6. Heat the water and observe the state of wax. Continue to heat till all the wax melts and note the approximate melting point.
7. Continue to heat the wax in the water bath till the temperatue is at least 20°C above the approximate melting point as observed in Step 6.
8. Turn off the burner, and carefully raise the clamp to remove the boiling tube from the water bath.

9. Record the readings of temperature after every 2 minutes.
10. Plot a graph of temperature of molten wax versus time, (temperature on *y*-axis and time on *x*-axis).
11. From the graph;
    (i) determine the melting point of wax.
    (ii) mark the time interval for which the wax is in liquid state.

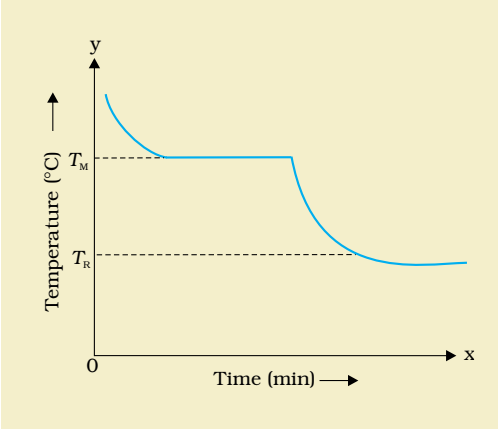


Fig. A 8.2: *Cooling curve*

OBSERVATIONS

Least count of thermometer = ... °C

Room temperature = ... °C

Least count of stop clock = ... s

Table A 8.1: Change in temperature of molten wax with time

S. No.	time (s)	temperature (°C)
1.		
2.		
3.		
4.		

RESULT

The cooling curve of molten wax is shown in the graph. From the graph (i) the melting point of wax is ... °C and (ii) the wax remains in liquid state for ... s.

PRECAUTIONS

1. The boiling tube containing wax should never be heated directly on a flame.
2. The stop clock should be placed on the right hand side of the apparatus as it may be easy to see.
3. Wax should not be heated more than 20°C above its melting point.

ACTIVITY 9

AIM

To observe and explain the effect of heating on a bi-metallic strip.

APPARATUS AND MATERIAL REQUIRED

An iron-brass bi-metallic strip with handle and a burner or a sprit lamp.

DESCRIPTION OF THE DEVICE

A bi-metallic strip is made of different metals having widely different values of coefficients of linear thermal expansion. The two metal strips of same dimensions are firmly rivetted lengthwise and fitted with a handle on one side.

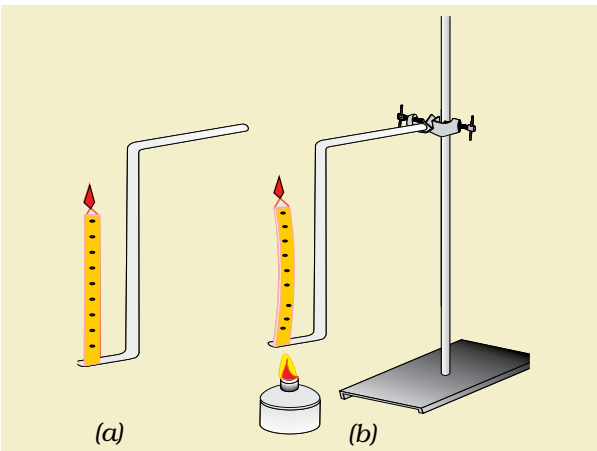


Fig. A 9.1: *A bi-metallic strip in (a) straight, and (b) bent positions*

The bi-metallic strip is straight at room temperature, as shown in Fig. A 9.1(a). When the bi-metallic strip is heated, both metallic pieces expand to different extents [Fig. A 9.1(b)]. As a result, the bi-metallic strip appears to bend.

PROCEDURE

1. Keep the bi-metallic strip in the vertical position over the flame of a burner by holding it in a laboratory stand. Note that which side of the bi-metallic strip is in direct contact of heat source.
2. Observe the effect of heating on the strip. Note carefully the direction of the bending of the free end of the bi-metallic strip, whether it is left or right.
3. Identify the metal (A or B) which is on the convex side of the bi-metallic strip and also the one which is on its concave side. Which one of the two metals have a larger thermal expansion? (The one on the convex side of the bi-metallic strip will expand more and hence have larger linear thermal expansion).
4. Note down the known values of coefficient of linear thermal expansion of two metals (A and B) of the bi-metallic strip. Verify

whether the direction of bending (left or right) is on the side of the metal/material having lower coefficient of linear thermal expansion.

5. Take the bi-metallic strip away from the heat source. Allow the strip to cool to room temperature. Observe what happens?
6. Repeat the Steps 1 to 3 to heat the other side of the bi-metallic strip. Observe the direction of bending of the bi-metallic strip. What change, if any, do you observe in the direction of bending of the strip in this case relative to that observed earlier.

RESULT

The bending of a bi-metallic strip on heating is due to the difference in coefficient of linear expansion of the two metals of the strip.

ACTIVITY 10

AIM

To study the effect of heating on the level of a liquid in a container and to interpret the observations.

APPARATUS AND MATERIAL REQUIRED

Boiling tube with a rubber cork filled with a narrow tube (about 20 cm long and of internal diameter 2 mm), glycerine, hot water, a 500 mL beaker or a trough, a stand for holding the boiling tube and a thermometer.

PROCEDURE

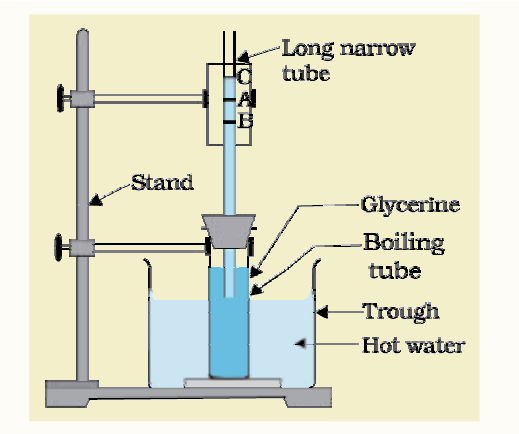


Fig. A 10.1: *Expansion of liquid (glycerine)*

1. Fill the boiling tube with glycerine up to the brim. Close its mouth with a tight fitting cork having a long narrow tube fixed in it. Glycerine will rise in the tube; mark the level of the glycerine in the tube as A. Set the apparatus as shown in Fig A 10.1.
2. Place the boiling tube in the beaker/ trough containing hot water and hold the boiling tube in position with the help of a stand as shown.

OBSERVATION

It is observed that as the boiling tube is lowered in hot water, the level of glycerine in the tube first falls down to a point, say B, and then rises up to a level C.

RESULT

Liquids expand on heating and the expansion in a liquid is more than the expansion of its container material for the same rise in temperature.

PRECAUTIONS

1. The cork in the boiling tube should be airtight.
2. The apparatus should be held vertical.
3. Be careful not to spill hot water.
4. Immerse as much part of boiling tube in hot water as practicable.

ACTIVITY 11

AIM

To study the effect of detergent on surface tension of water by observing capillary rise.

APPARATUS AND MATERIAL REQUIRED

A capillary tube, a beaker of 250 mL, small quantity of solid/liquid detergent, 15/30 cm long plastic scale, rubber band, laboratory stand with clamp and water.

PROCEDURE

1. Take a capillary tube of uniform bore. Clean and rinse it with distilled water. Also clean and rinse the beaker with water. Pour water to fill the beaker up to half. Make sure that the capillary tube is dry and free from grease, oil, etc. Also check that the top of the capillary tube is open and not blocked by anything.
2. Take a plastic scale and mount the capillary tube on it using rubber bands.
3. Hold the scale with capillary in vertical position with the help of a clamp stand.
4. Place the half filled beaker below the lower end of the scale with capillary tube. Gradually lower the scale till its lower end gets immersed below the surface of water in the beaker as shown in Fig. A 11.1.
5. Read the position of the water level inside and outside the capillary tube on the scale. Let the positions be h_2 and h_1 respectively. The rise of water in the capillary is $h = h_2 - h_1$.
6. Rinse the capillary thoroughly in running water and dry it.

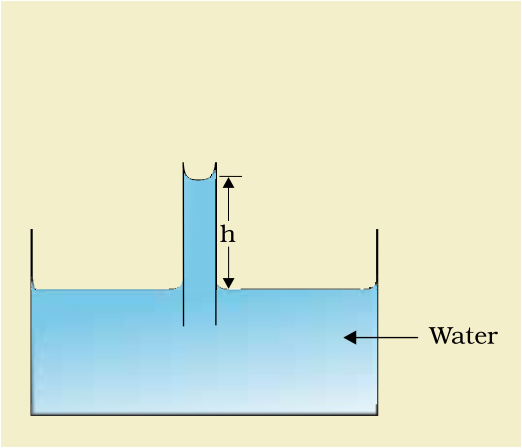


Fig. A 11.1: *Rise of water in capillary tube*

7. Take a little quantity of the given detergent and mix it with water in the beaker.
8. Repeat the Steps 2 to 5 with detergent solution and find capillary rise again. Let it be h′.

Note: The concentration of detergent must not be made high, otherwise the density of solution (colloidal) will change substantially as compared to water.

OBSERVATIONS

The height of the water rose in the capillary h = ... cm.

The height of the detergent solution rose in the capillary

h′ = ... cm.

RESULT

The capillary rise of detergent solution h′ is less than the capillary rise of water, h.

PRECAUTIONS

1. The inner surface of the beaker and the part of capillary tube to be immersed in water or solution in the beaker should not be touched by hand after cleaning them. This is essential to avoid contamination by the hand.
2. To wet the inside of the capillary tube freely, it is first dipped down in the water and then raised and clamped. Alternatively, the beaker may be lifted up and then put down.

ACTIVITY 12

AIM

To study the effect of load on depression of a suitably clamped metre scale loaded;

(i) at its end

(ii) in the middle.

(i) Bending of a metre scale loaded at its end

APPARATUS AND MATERIAL REQUIRED

Metre scale (or a thick wooden strip of about 1 m length), thread, slotted weights with hanger (10 g, 20 g, 50 g, 100 g), another set of 5 weights each of 200 g, graduated scale to be used to measure depression, a pair of wedges, a pin, cellotape and clamp.

PROCEDURE

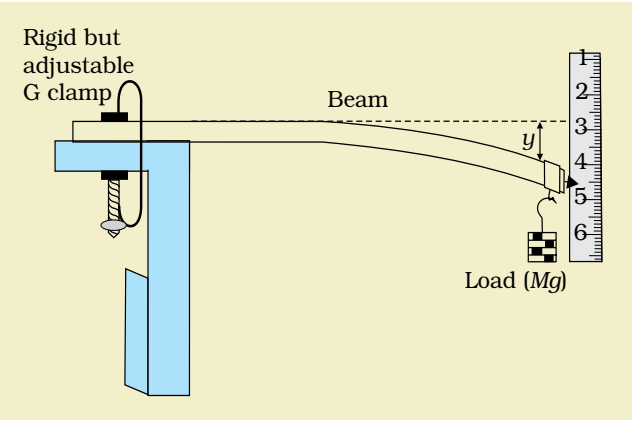


Fig. A 12.1: *Experimental set up to study depression of metre scale (used as cantilever) with load suspended at free end of the cantilever*

1. Clamp the metre scale firmly to the edge of the table. As shown in Fig. A.12.1. Ensure that the length and breadth of the scale are in horizontal plane and 90 cm of the length of the scale is projected out. Fix a pin with a tape at the free end of the metre scale along its length to act as a pointer.
2. Fix a graduated scale vertically near the free end of the clamped metre scale and note its least

count. Ensure that the pointed end of the pin is just above the graduation marks of the scale but do not touch it.

3. Read the pointer 'p' when metre scale, i.e., the cantilever is without any load.
4. Suspend a hanger of known mass for keeping slotted weights to depress the free end of the cantilever or scale.
5. Read the pointer on vertical scale and record your observations in Table A 12.1.
6. Keep on adding masses to the hanger and record the reading of the pointer everytime when it stops vibrating.
7. After taking 6–7 observations with increasing load, gradually remove the slotted weights one by one and record the reading while unloading.
8. Plot a graph between the depression and the load.

OBSERVATION

Reading of the free end of the cantilever with no load, l_0=.... cm

Table A 12.1: Effect of load on depression of cantilever

S. No.	Load M (g)	Reading of free end of cantilever			Depression $y = l_m - l_o$
	l_1 (cm) when load is increasing	l_2 (cm) when load is decreasing	Mean $l_m = \frac{l_1 + l_2}{2}$ (cm)		
1.					
2.					
3.					
4.					
5.					
6.					
7.					

RESULT

The graph between depression and load is a straight line which shows that depression 'y' is directly proportional to the load Mg.

PRECAUTIONS

1. The scale should be rigidly clamped at one end.
2. Loading and unloading of the slotted weights should be done carefully without disturbing the position of the hanger on the beam.
3. The vertical scale should be adjusted close to the pointer in such a way that the pointer moves along it freely.

(ii) Bending of metre scale loaded in the middle

PROCEDURE

1. Place the metre scale on two wedges with (5–10 cm) length projecting out on either side. Metre scale supported at both ends is like a beam.
2. Tie a loop of thread in the middle of the load such that a hanger to support slotted weights each of 200 g can be suspended on it. Ensure that the thread is tied tightly with the rod and does not slip.
3. Place a graduated scale (with least count 0.1 cm) vertically in a stand at the centre of the metre scale used as a beam. To facilitate readings, the vertical scale should be kept on the far side of the metre scale. Fix a pin to the hanger such that its pointed end is close to the edge of the vertical scale which has graduation marks on it.
4. Suspend the hanger of mass 200 g and record the position of the pointer fixed to the hanger. The mirror strip on the vertical scale should be fixed to remove any parallax.

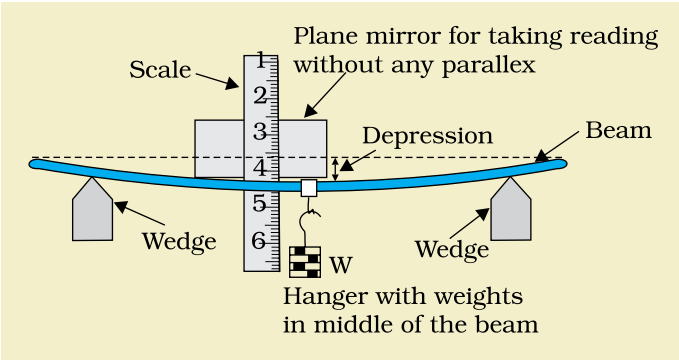


Fig. A 12.2: *Experimental set up to study depression, i.e., sag of a beam with load in the middle*

5. Keep on adding 200 g slotted masses to the hanger and record the readings of the pointer each time.
6. Take about six observations.
7. Now, remove masses of 200g one by one recording the position of the pointer each time while unloading.

8. Find the mean the depression for the load M and hence depression per unit load.

9. Plot a graph between the values of depression y against corresponding values of load and interpret the result.

OBSERVATIONS

Length of the beam between the wedges, L = … cm

Table A 12.2 Depression of the beam for different loads

S. No.	Load M (g)	Reading of the centre of cantilever			Depression for load M (g), y (cm)	Depression per unit load y/M (cm/g)	Mean y/M (cm/g)
		Load increasing r'_1 (cm)	Load decreasing r'_2 (cm)	Mean reading (cm)			
1.	0			r_o	0		
2.	200			r_1	r_1-r_o		
3.	400			r_2	r_2-r_o		
4.							
5.							
6.							

RESULT

The depression of the metre scale at its middle is … mm/g. The depression 'y' is directly proportional to the load M.

PRECAUTIONS

1. The beam should be symmetrical on the knife edges.

2. Loading and unloading of the slotted weights should be done carefully without disturbing the centre point.

3. Mirror strip used to eliminate parallax error should not disturb the experimental setup.

4. The rod should not be loaded beyond elastic limit.

EXPERIMENT 1

AIM

To determine the resistance per unit length of a given wire by plotting a graph of potential difference versus current.

APPARATUS AND MATERIAL REQUIRED

A wire of unknown resistance (approximately 50 cm long), a rechargeable battery or two dry cells (1.5 V each) with cell holder, two multimeters, rheostat, plug key, connecting wires and a piece of sand paper.

FORMULA USED

We know that,

$V = RI$ or $R = \frac{V}{I}$ *or*

$$I = \frac{V}{R} = \frac{1}{R} \times V \qquad \text{(E 1.1)}$$

Where V is the potential difference across the ends of the unknown resistance and I is current flowing through it.

A linear relationship is obtained between V and I, i.e. the graph between V and I will be a straight line passing through the origin as shown in Fig. E 1.1. The slope of the graph is $1/R$ from the equation E 1.1 (Equation of straight line passing through origin is y = mx where m is the slope of graph).

$$\text{Slope} = \frac{1}{R} = \frac{AB}{BC}$$

$$\Rightarrow R = \frac{1}{\text{slope}}$$

If l is the length of wire then the resistance per unit length of the wire $= \frac{R}{l}\ \Omega\ \text{m}^{-1}$

PROCEDURE

1. Clean the ends of the connecting wires with the help of sand paper in order to remove any insulating coating on them.

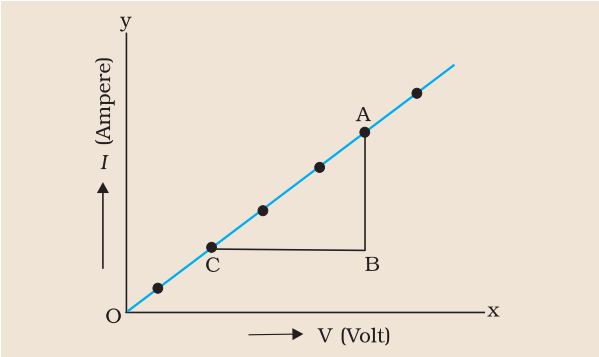


Fig. E 1.1: *Graph between current I and potential difference V*

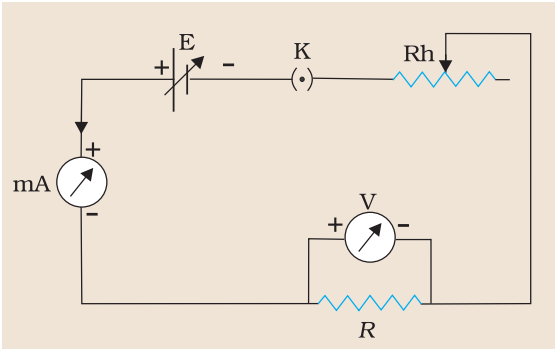


Fig. E 1.2: *Circuit to find the relation between current I and potential difference V for a given wire*

2. Connect various components—resistance wire, rheostat, battery, key, one multimeter used as a voltmeter and another multimeter used as milliameter as shown in Fig. E 1.2.
3. Set multimeter used as milliammeter for range of 0–200 mA and multimeter used as voltmeter for range of 0–2V.
4. Note the least count of the multimeters for current and polentail difference scales.
5. Insert the key K and slide the rheostat contact to one of its extreme ends, so that current passing through the resistance wire is minimum.
6. Note the milliammeter and voltmeter readings.
7. Remove the key K and allow the wire to cool, if heated. Again insert the key. Shift the rheostat contact slightly to increase the applied voltage. Note the milliammeter and voltmeter reading.
8. Repeat Step 7 for four different settings of the rheostat. Record your observations in a tabular form.

OBSERVATIONS

1. Range of ammeter = 0 mA to ....mA
2. Least count (L.C.) of ammeter = ...mA
3. Range of voltmeter = 0 V to V
4. Least count of Voltmeter = ...V
5. Least count of metre scale = ...m
6. Length of the given wire, l = ...m

1_XII_Experiment_1_2 Folder.indd 95 08-10-2018 14:16:12

Table E 1.1: Variation in current with change in potential difference

S. No.	Applied potential difference [voltmeter reading V]	Current flowing through the wire [milliammeter reading I]
	V (Volt)	I (mA)
1.		
2.		
–		
3.		

CALCULATIONS

1. Plot a graph between the potential difference across the wire (V) and the current (I) flowing through it as shown in Fig. E 1.1
2. Determine the slope of the graph. The resistance of the given wire is then equal to the reciprocal of the slope.

   From the graph $R = \frac{V}{I}$ *or* $I = \frac{V}{R} = \frac{1}{R} \times V$
3. Resistance per unit length of given wire = $\frac{R}{l} = ... \ \Omega m^{-1}$.

RESULT

1. The potential difference across the given wire varies linearly with the current.
2. The resistance per unit length of the wire is = ... Ωm^{-1})

PRECAUTIONS

1. The multimeter used for measuring voltage should be connected in parallel and the multimeter used for measuring current should be connected in series in the circuit. One should ensure that the current in the multimeters enters through positive (red) terminal.
2. The key should be inserted only while taking observations, as excessive flow of current causes unnecessary heating of the wire.

1_XII_Experiment_1_2 Folder.indd 96 08-10-2018 14:16:12

EXPERIMENT 2

AIM

To determine the resistance of a given wire using a metre bridge and hence determine the resistivity of the material of the wire.

APPARATUS AND MATERIAL REQUIRED

Improvised metre bridge as given in the kit, a wire about 1m long (of material whose specific resistance is to be determined), a resistance box (dial type), a rheostat, galvanometer, a jockey, one-way key, a 2V rechargeable battery, connecting wires, sand paper and screw gauge.

DESCRIPTION OF APPARATUS

Metre Bridge

The metre bridge provided in the kit consists of two similar halves (about 55cm × 7.5cm) each provided with a half metre scale in continuity to make a 1m scale. A thick metallic strip with a gap and four terminals is also provided as shown in the diagram.

Provision is made to attach the two halves strongly and securely to make the metre bridge. A metallic strip is also provided to be fixed between B and B1 after the two halves are attached.

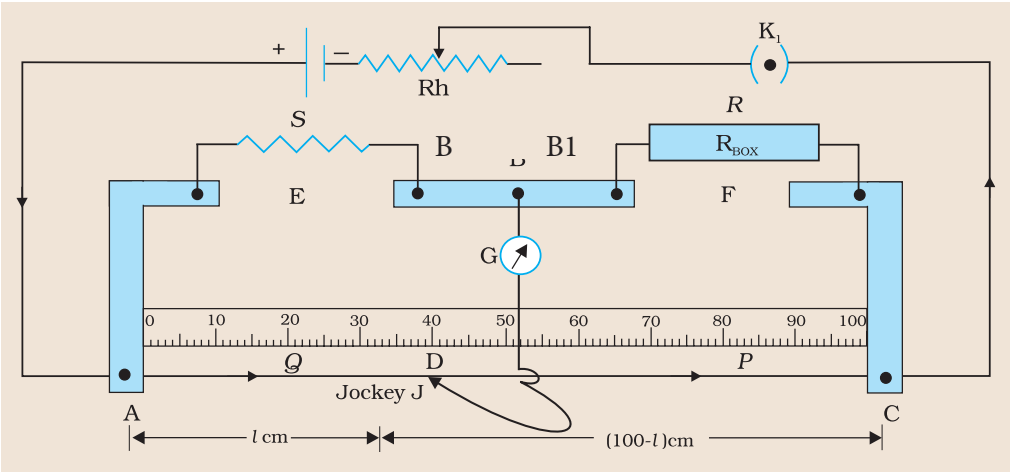


Fig. E 2.1: *A metre bridge*

PRINCIPLE

A meter bridge works on the principle of wheatstone's bridge. In a wheatstone's bridge if circuit is complete and there is no deflection in the galvanometer G, then the bridge is in the balance condition.

In this condition,

$$\frac{P}{Q} = \frac{R}{S} = \frac{\textit{Resistance of wire of lengh DC}}{\textit{Resistance of wire of lengh AD}}$$

Unknown resistance S of the wire, having uniform cross-sectional area is given by

$$S = R \times \left(\frac{l}{100 - l}\right)$$

FORMULA USED

Formula used for a balanced bridge,

$$\frac{P}{Q} = \frac{R}{S}$$

From the diagram E 2.1

$$\frac{100 - l}{l} = \frac{R}{S}$$

or

$$S = \left(\frac{l}{100 - l}\right) R$$

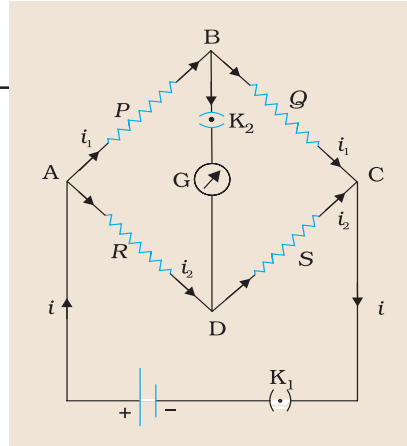


Fig. E 2.2: *The wheatstone's bridge*

Also the specific resistance or resistivity of the material is given by,

$$\rho = \frac{Sa}{L} \quad or \quad \rho = \frac{S\pi r^2}{L}$$

where, S is the resistance of the wire of length L and $a = \pi r^2$ (r being the radius) is area of cross section.

PROCEDURE

1. Assembling the meter bridge

   (a) Join the two parts of the metre bridge. Such that scale reads

1_XII_Experiment_1_2 Folder.indd 98 08-10-2018 14:16:13

from 0 to 100 cm. Clamp the two parts together by using the metallic strip provided, in the middle gap.

(b) Fix the metre bridge wire between the two terminals at the ends of the metre scale in such a way that there are no kinks in the wire. Kink in the wire, if any, may be removed by tightening the wire with a screw at one end and stretching the other terminal. Tight the other terminal as well so that 1m length of the wire remains stretched between the two terminals without any kink. To remove the kinks you may need to rub the stretched wire with a thick paper or soft cloth.

2. Find the average diameter of the unknown resistance wire with a screw gauge. From this, obtain the value of its radius *r*. Measure the length of the wire L.

3. Remove metallic strips from gaps E and F clean the insulation at the ends of connecting wires with a piece of sand paper.

4. Set up the circuit as shown in Fig. E 2.1 with unknown resistance wire of known length in gap E.

5. Next, introduce some resistance R in the circuit from the resistance box. Bring the jockey J in contact with terminal A first and then with terminal C. Note the direction in which pointer of the galvanometer gets deflected in each case. Make sure that jockey remains in contact with the terminals for a fraction of a second. If the galvanometer shows deflection on both sides of its zero mark for these two points of contact of the jockey, null point will be somewhere on the wire AC. If it is not so, adjust resistance R so that the null point is somewhere in the middle of the wire AC, say, between 30 cm and 70 cm.

6. If there is one-sided deflection check the circuit again, especially junctions for their continuity.

7. Repeat the above steps for five different values of resistance R. Value of the resistance of the given wire based on this observation may be denoted by S_1.

8. Interchange the position of the resistance S and R and repeat the above steps for the same five values of R. Value of the resistance of the given wire using those observations may be denoted by S_2. While interchanging S and R, ensure that the same length of wire of resistance S is now in the gap F. The interchange takes care of unaccounted resistance offered by the terminals.

OBSERVATIONS

1. Length of the wire of unknown resistance, L = ...cm

1_XII_Experiment_1_2 Folder.indd 99 08-10-2018 14:16:13

2. Measurement of the diameter of wire of unknown resistance

Least count of the screw gauge (L.C.) = ... mm

Zero error of the screw gauge = ...mm

Zero correction of the screw gauge = ...mm

Table E 2.1: Diameter of the wire

S. No.	Reading along one direction			Reading along mutually perpendicular direction			Mean Diameter
	Main scale reading p (mm)	Coinciding circular scale division n	Diameter d_1=p+n × L.C.	Main scale reading p'(mm)	Coinciding circular scale division n'	Diameter d_2 p'+n' × L.C. (mm)	d= $\frac{d_1+d_2}{2}$ (mm)
1.							
2.							
3.							

Mean diameter (corrected for zero error) = ... mm
Radius of the wire r = ... mm

Table E 2.2: Resistance of the given wire

S. No.	S in the left gap E					S in the right gap R					
	Resistance R Ω (ohm)	Posotion of balance point D (cm)	Balanceing lenght AD (l) (cm)	Length DC=100 – l (cm)	$S_1 = R \times \frac{l}{100-l}$ Ω (ohm)	Position of balance point D' (cm)	Balancing length AD'=100-l' (cm)	Length D'C'=100-l' (cm)	$S_2 = R \times \frac{100-l'}{l'}$ Ω (ohm)	Means resistence $S = \frac{S_1+S_2}{2}$ (cm)	ρ Ω m
1.											
2.											
-											
5.											
									Mean		

1_XII_Experiment_1_2 Folder.indd 100 08-10-2018 14:16:14

CALCULATIONS

L = … cm r = … mm S = … Ω

Substituting these values in $\rho = S\frac{\pi r^2}{L}$, calculate the value of ρ in ohm-m.

RESULT

1. The unknown resistance of the given wire is found to be S=… Ω
2. The resistivity of the material of the wire is ρ = ... Ωm.

PRECAUTIONS

1. Ensure that there are no kinks and the wire is taut.
2. All the connections and plugs should be tight.
3. Jockey should be moved gently over the metre bridge wire.
4. The plug in the key (K_1) should be inserted only at the time of taking observations.
5. Balance points should be in the middle of the wire (30 cm to 70 cm).
6. Initially a thick copper wire across the terminals of the galvanometer may be used as shunt while determining the balance point. However, shunt should be removed while determining the exact balance point.
7. Open the plug key when not taking any reading to prevent unnecessary battery drain and heating of wires.

SOURCES OF EFFOR

1. The metre bridge wire may not be of uniform area of cross-section.
2. Effect of end resistances due to metallic strips and connecting screws, may affect the measurement.
3. The length L of the wire should not include the lengths below the terminals when placed in gap E or F.
4. The resistances of end pieces/metal strips may not be negligible. The error introduced by it can be reduced by interchanging the known and unknown resistances in gaps E and F.

1_XII_Experiment_1_2 Folder.indd 101 08-10-2018 14:16:14

5. The length measurements may have error if the metre bridge wire is not taut and along the scale in the metre bridge.
6. Galvanometer pointer is expected to be at zero when no current flows through it. However, many times it is observed that it is not so. In such cases, pointer has to be adjusted to zero by gently moving the screw below the scale with the help of a screw driver. If it is not possible to adjust the pointer, the balance point should be considered at the point at which tapping of the jockey does not show any deflection in the galvanometer.

1_XII_Experiment_1_2 Folder.indd 102 08-10-2018 14:16:14

EXPERIMENT 3

AIM

To verify the laws of combination of resistances (series and parallel) using a metre bridge.

APPARATUS AND MATERIAL REQUIRED

Improvised metre bridge, a sensitive galvanometer, two different resistors as given in the kit, a resistance box (dial type), a jockey, a rheostat, a plug key, a 2V rechargeable battery, connecting wires and a piece of sand paper.

PRINCIPLE

When two resistances R_1 and R_2 are connected in series (Fig. E 3.1), the resistance of the combination R_S is given by,

$$R_S = R_1 + R_2 \qquad \text{(E 3.1)}$$

When connected in parallel (Fig. E 3.2), the resistance R_P of the combination is given by,

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \qquad \text{(E 3.2)}$$

PROCEDURE

1. Assemble the metre bridge following the steps given in Experiment 2.
2. Replace the unknown resistance S with a series combination of R_1 and R_2 and determine its value.
3. Replace the unknown resistance S with a parallel combination of R_1 and R_2 and determine its value.
4. Note resistance R and lengths AD and DC in the observation table.

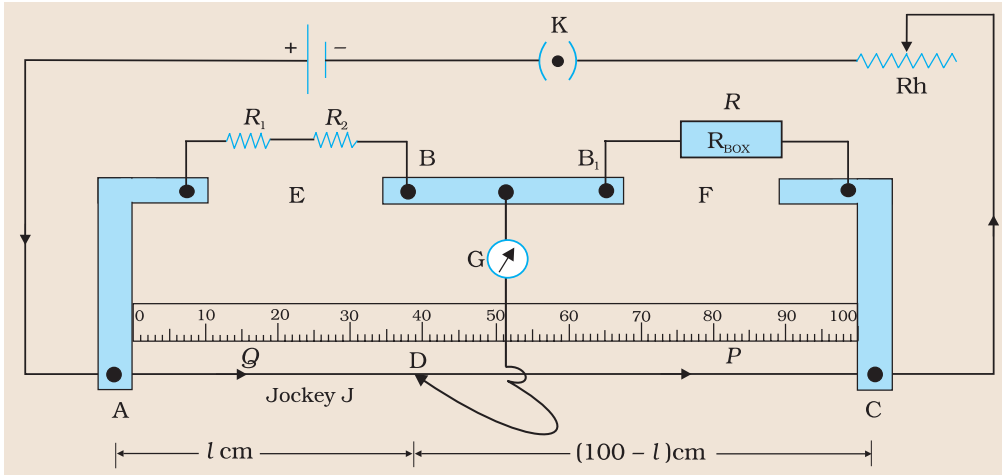


Fig. E 3.1: *Resistances R_1 and R_2 connected in series to one arm of a metre bridge*

OBSERVATION

Table E 3.1: Series and parallel combination of resistances

	S. No.	Resistance R	Length AD = l	Length DC, $l' = 100 - l$	Unknown resistance of the combination $R_s\ (or\ R_p) = \frac{R \times l}{l'}$
		(ohm)	(cm)	(cm)	(ohm)
R_1 and R_2 is series R_s	1.				
	2.				
	--				
	5.				
					Mean R_s=
R_1 and R_2 in parallel R_p	1.				
	2.				
	--				
	5.				
					Mean R_p=

CALCULATIONS

1. The theoretically expected value of the series combination of resistances is $R_S = R_1 + R_2$

2_XII_Experiment_3 Folder.indd 104 05-10-2018 14:49:03

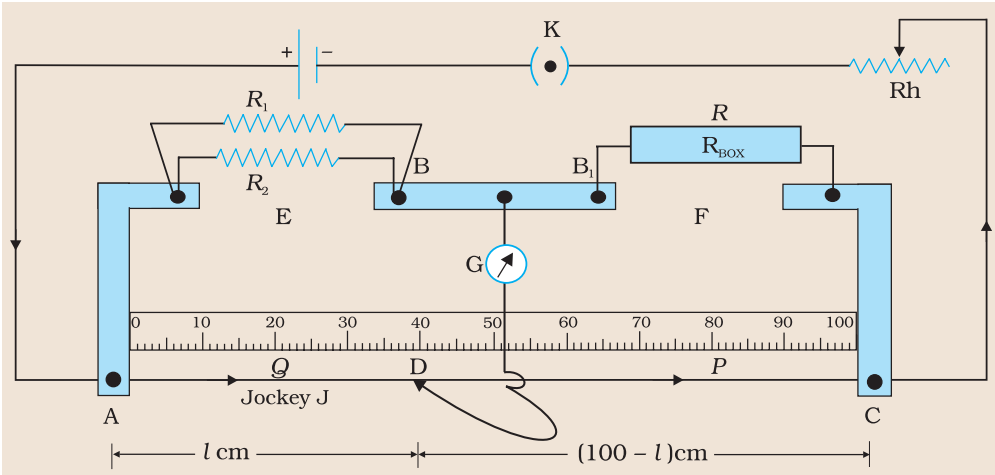


Fig. E 3.2: *Resistances R_1 and R_2 connected in parallel to one arm of a metre bridge*

Note: R_1 and R_2 are to be obtained from colour code on carbon resistors or are the given values in case of resistances made of wires of materials like nichrome, constantan, etc.

2. Theoretically expected value of the parallel combination of resistances is, $R_p = \dfrac{R_1 R_2}{R_1 + R_2}$

Percentage Error

$$\% \text{ error} = \frac{\text{standard (theoretical) value} - \text{Measured value}}{\text{standard (theoretical) value}} \times 100$$

RESULT

Table E 3.2: Theoretical and experimental values of resistance

	Theoretically expected resistance ( )	Experimentally obtained resistance ( )	Difference between theoritical and experimental values	% error
Series Combination	R1 + R2			
Parallel Combination	$\dfrac{R_1 R_2}{R_1 + R_2}$			

2_XII_Experiment_3 Folder.indd 105 05-10-2018 14:49:04

PRECAUTIONS

1. Ensure that there are no kinks and the wire is taut.
2. All the connections and plugs should be tight.
3. Jockey should be moved gently over the metre bridge wire.
4. The plug in the key (K) should be inserted only at the time of taking observations.
5. Balance points should be in the middle of the wire (30 cm to 70 cm)
6. Initially a thick copper wire across the terminals of the galvanometer may be used as shunt while determining the balance point. However, shunt should be removed while determining the exact balance point.
7. Open the plug key when not measuring any reading to prevent unnecessary battery drains.

SOURCES OF ERROR

1. The metre bridge wire may not be of uniform area of cross-section.
2. Effect of end resistances due to metallic strips and connecting screws, may affect the measurement.
3. The length L of the wire should not include the lengths below the terminals when placed in gap E or F.
4. The resistances of end pieces/metal strips may not be negligible. The error introduced by it can be reduced by interchanging the known and unknown resistances in gaps E and F.
5. The length measurements may have error if the metre bridge wire is not taut and along the scale in the metre bridge.
6 Galvanometer pointer is expected to be at zero when no current flows through it. However, many times it is observed that it is not so. In such cases, pointer has to be adjusted to zero by gently moving the screw below the scale with the help of a screw driver. If it is not possible to adjust the pointer, the balance point should be considered at the point at which tapping of the jockey does not show any deflection in the galvanometer.

2_XII_Experiment_3 Folder.indd 106 05-10-2018 14:49:04

EXPERIMENT 4

AIM

To compare the emf of two given primary cells (Daniel and Leclanche cells) using a potentiometer.

APPARATUS AND MATERIAL REQUIRED

An improvised potentiometer, a Leclanche cell, a Daniel cell, a two-way plug key, a resistance box (0 to 1000 Ω), a galvanometer, a 2V battery, a low resistance rheostat (30Ω), a one-way plug key, one jockey, connecting wires and sand paper.

DESCRIPTION OF APPARATUS

Potentiometer

The potentiometer provided in the kit consists of a uniform wire AB of length 500 cm (Fig 4.1) the wire is made of a material of low temperature coefficient of resistance. The wire AB is fixed on a wooden board with a 50 cm scale fixed alongside.

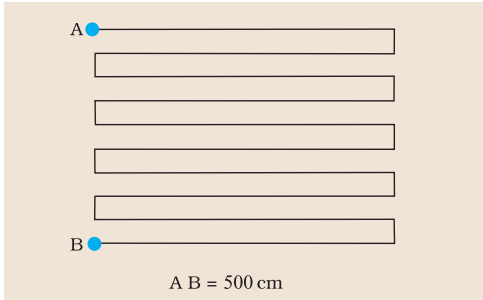


Fig. E 4.1

FORMULA USED

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

where, E_1 and E_2 are emfs of two cells. l_1 and l_2 are the balancing lengths when E_1 and E_2 are connected to the circuit respectively.

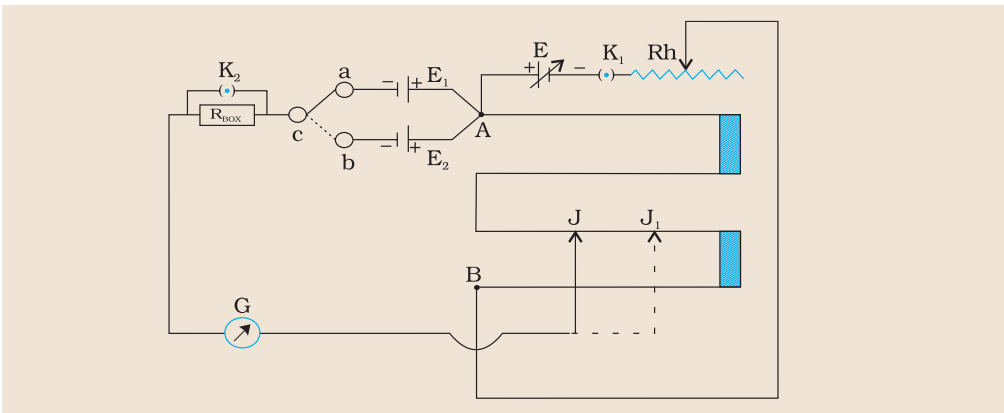


Fig. E 4.2: *Circuit to compare the emf of two primary cells*

PROCEDURE

1. Set up the circuit according to Fig. E 4.2. Connect positive terminals of the battery E and the two cells E_1 and E_2 to the end A, i.e., zero of the potentiometer wire.

2. Connect negative terminal of E to the end B of the potentiometer wire through a one-way key K_1 and a rheostat.

3. Connect negative terminals of the cell E_1 and E_2 to the terminals 'a' and 'b' of the two-way key.

4. Shunt a resistance box R_{BOX} through a key K_2. Connect common terminal of the two-way key to one end of R_{BOX}. Use thick copper wire as a shunt.

5. Connect other end of the resistance box to a galvanometer of which the other terminal is joined to a jockey using at least 30 cm long connecting wire.

3_XII_Experiment_4 Folder.indd 108 05-10-2018 12:36:00

6. Plug in the key K_1 to allow current to pass through the potentiometer wire.

7. Insert the plug between the gaps 'a' and 'c' of the two-way key so that the cell E_1 is connected into the circuit.

8. Leave the key K_2 open. Set the rheostat slider to minimum resistance. Introduce high resistance (of the order of thousand ohm) in the circuit with resistance box. Make contact of the jockey at the zero end of the potentiometer wire. Note the direction of deflection in the galvanometer.

9. Next, move the jockey to bring it in contact with the other end B of the wire. Note whether the direction of deflection of the galvanometer needle is opposite to that observed in the preceding step.

10. If the deflection of galvanometer needle is in opposite direction in the above two situations, connections are correct. If not, look out for the reason. Connections might be loose or emf of the battery E might be less than that of the cell E_1, Make necessary changes as required.

11. Slide the jockey gently over the potentiometer wire till you get null deflection in the galvanometer. Plug in the key K_2 to get the accurate position of the null (or balance) point. The resistance in the resistance box limits the current flowing through the galvanometer. Near the balance point, the current flowing through the galvanometer is small. Insertion of the key K_2 short circuits the resistances and hence increases the current. This improves the sensitivity of balance point detection.

12. Note the length of the wire AJ, and record it as l_1.

13. Next bring E_2 in the circuit by inserting plug between the gaps 'b' and 'c' of the two-way key without disturbing the position of slider of the rheostat. Obtain the balance point J_1 in the same way as you did in finding l1 and note the length AJ_1 as l_2.

14. Repeat the above steps four times by shifting the contact point of the rheostat and note l_1 and l_2 for each case respectively.

15. Record your observations in tabular form.

3_XII_Experiment_4 Folder.indd 109 05-10-2018 12:36:00

OBSERVATIONS

Table E 4.1: Balance length

S. No.	l_1 cm	l_2 cm	Ratio $\frac{E_1}{E_2} = \frac{l_1}{l_2}$
	Leclanche cell (E1) in the circuit	Daniel cell (E2) in the circuit	
1.			
2.			
3.			
4.			
		Mean	

CALCULATIONS

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} = ...$$

RESULT

The ratio of emfs E_1/E_2 for Leclanche cell to Daniell cell,

$$\frac{E_1}{E_2} = ...$$

PRECAUTIONS

1. Battery should be fully charged. Check it by using a multimeter.
2. All connections should be tight and potentiometer wire should be taut.
3. Jockey should be pressed gently on the potentiometer wire to prevent formation of any kinks in it.
4. Position of rheostat contact should not be disturbed before finishing the task of finding the balance length with both the cells.
5. Key should be plugged only when the observations are being taken.

3_XII_Experiment_4 Folder.indd 110 05-10-2018 12:36:01

EXPERIMENT 5

AIM

To determine the internal resistance of a given primary cell using a potentiometer.

APPARATUS AND MATERIAL REQUIRED

Improvised potentiometer, Leclanche cell (a new dry cell can be used), multimeter, two dial type resistance boxes (about 0-50 Ω), three one-way plug keys, galvanometer, a low resistance rheostat (200 Ω) jockey, battery eliminator (0-10 V, 500 mA) and connecting wires.

FORMULA USED

The internal resistance r, of the cell is given by

$$r = \left(\frac{l_0 - l}{l}\right)R \qquad \text{E 5.1}$$

where l_o is the distance of the null point from end A of the potentiometer with key K_2 open, l is the distance of the null point from end A when key K_2 is closed with resistance R introduced in the circuit through resistance box.

PROCEDURE

1. Connect different electrical components as shown in the circuit (Fig. E 5.1). After checking the circuit connections, close key K_1. Use multimeter as an ammeter.
2. Set the resistance value in R_{BOX2} between 1-2K.

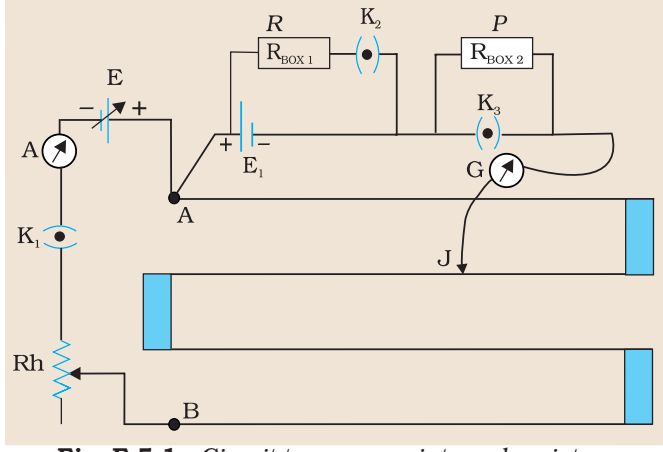


Fig. E 5.1: *Circuit to measure internal resistance of a primary cell using a potentiometer*

3. Check deflection in galvanometer with the jockey at terminal A and then at B. Deflections should be on opposite sides. If this is not so, adjust rheostat to get deflection on both sides.

4. With key K_2 open, find the position of the balance point. For final reading close the key K_3 and find the balance length l_O.

5. Take R = 10 Ω (from R_{BOX1}), close the key K_2 and quickly measure the new balance length l. Open key K_2 as soon as this is done.

6. Keep the reading in the ammeter constant throughout the above observations using the rheostat.

7. Reduce the value of R in equal steps (say of 1Ω, 2Ω) and for each value of R obtain the balance length l, as done in step 4.

8. At the end of the experiment, open key K_2 and repeat step 4 to find l_0 again.

OBSERVATIONS

l_0 = ... cm (in the beginning of the experiment)

l_0 = ... cm (at the end of the experiment)

Mean l_o= ... cm.

Table E 5.1: Balance length

S. No.	R (Ω)	l (cm)	$\frac{1}{R}$ (Ω^{-1})	$\frac{1}{l}$ (cm^{-1})	$r=\left(\frac{l_o-l}{l}\right)R(\Omega)$
1.					
2.					
--					
6.					

CALCULATIONS

1. Substitute the value of l_0, l and corresponding value of R in Eq. (E 5.1) and calculate the value of r.

2. Use graphical method also to obtain r. Note that Eq (E 5.1) can be written as

$$\frac{1}{R}=\frac{l_0}{r}\left(\frac{1}{l}\right)-\frac{1}{r}$$

4_XII_Experiment_5 Folder.indd 112 04-10-2018 17:11:23

It is an equation of a straight line (Fig. E 5.2).

3. Plot a graph between 1/R and 1/*l*, taking $\frac{1}{l}$ on the x-axis and $\frac{1}{R}$ on *y-axis*.

4. Draw a straight line as close to the points plotted as you can. The negative intercept on the y-axis gives the value of 1/r. Hence, obtain the value of r (Fig. E 5.2).

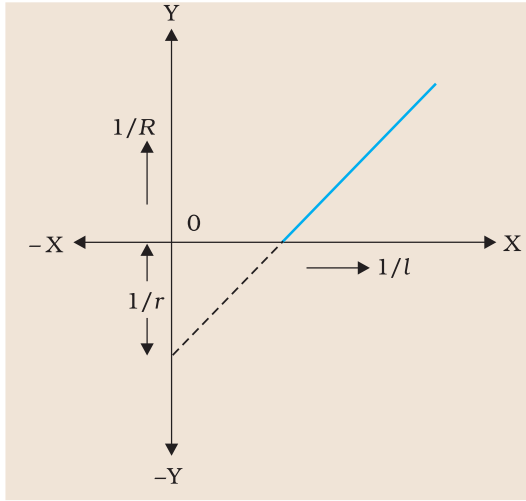


Fig. E 5.2: *Graph between 1/R and 1/l*

RESULT

The internal resistance of the given cell r

(i) by calculation = ... Ω

(ii) by graph = ... Ω

PRECAUTIONS

1. The primary cell whose internal resistance is to be determined should not be disturbed during the experiment or else its internal resistance may change.

2. The emf of battery E should be more than the emf of the primary cell, E_1.

3. Positive terminals of E and E_1 both should be connected at the same point on the potentiometer.

4. Always measure length from point A, i.e., the point at which positive terminals of battery are connected and measure this length up to the balance point.

5. Insert K_1 and K_2 only when readings are taken, otherwise the wires may get heated up due to continuous flow of current and may also affect the internal resistance of the cell.

6. Ensure constant currents value in multimeter for each observations.

7. Keep the output of eliminator between 4–6 V.

4_XII_Experiment_5 Folder.indd 113 04-10-2018 17:11:23

EXPERIMENT 6

AIM

To determine the resistance of a galvanometer by half-deflection method and to find its figure of merit.

APPARATUS AND MATERIAL REQUIRED

A moving coil galvanometer, a 2V battery, two resistance boxes two one-way keys connecting wires and sand paper.

PRINCIPLE

Galvanometer

Galvanometer is a sensitive device used to detect very low current. Its working is based on the principle that a coil placed in a uniform magnetic field experiences a torque when an electric current is set up in it. The deflection of the coil is determined by a pointer attached to it, moving on the scale.

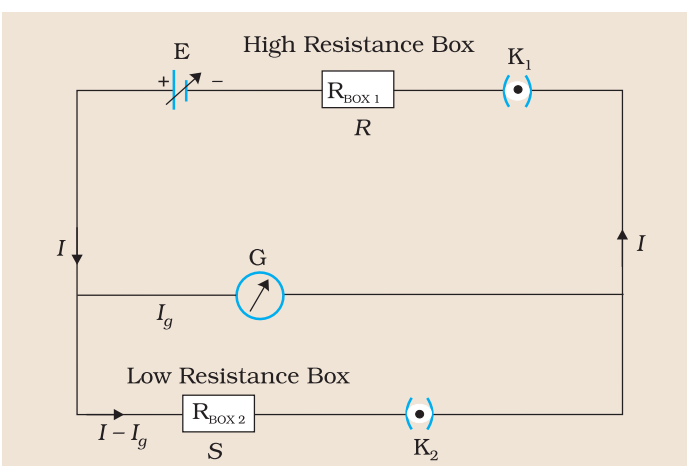


Fig. E 6.1: *Circuit for finding resistance of galvanometer*

When a coil carrying current I is placed in a radial magnetic field, the coil experiences a deflection θ which is related to I as,

$$I = k\theta \qquad \text{(E 6.1)}$$

where k is a constant of proportionality and is termed as figure of merit of the galvanometer.

The circuit arrangement required for finding the resistance G of the galvanometer by half deflection method is shown in Fig. E 6.1.

When a resistance R is introduced in the circuit, the current I_g flowing through the galvanometer is given by,

$$I_g = \frac{E}{R+G} \qquad \text{(E 6.2)}$$

In this case, the key K_2 is kept open. Here E is the emf of battery, G is the resistance of the galvanometer whose resistance is to be determined.

If the current I_g produces a deflection θ in the galvanometer, then from equation (E 6.1) we get,

$$I_g = k\,\theta \qquad \text{(E 6.3)}$$

Combining equations (E 6.2) and (E 6.3) we get,

$$\frac{E}{R+G} = k\,\theta \qquad \text{(E 6.4)}$$

On keeping both the keys K_1 and K_2 closed and by adjusting the value of shunt resistance S, the deflection of the galvanometer needle is made $\frac{\theta}{2}$.

As G and S are in parallel combination and R in series with it, the total resistance of the circuit,

$$R' = R + \frac{GS}{G+S} \qquad \text{(E 6.5)}$$

The total current, I due to the emf E in the circuit is given by,

$$I = \frac{E}{R + \frac{GS}{G+S}} \qquad \text{(E 6.6)}$$

If I'_g is the current flowing through the galvanometer of resistance G, then

$$G\,I'_g = S\,(I - I'_g)$$

or,

$$I'_g = \frac{IS}{G+S} \qquad \text{(E 6.7)}$$

5_XII_Experiment_6_7 Folder.indd 115 05-10-2018 12:38:07

Substituting the value of I from equation (E 6.6), in equation (E 6.7) the current I'_g is given by,

$$\left[I'_g = \frac{IS}{G+S} = \frac{E}{R+\frac{GS}{G+S}} \cdot \frac{S}{G+S} \right]$$

$$I'_g = \frac{ES}{R(G+S)+GS} \qquad \text{(E 6.8)}$$

For galvanometer current I'_g, if the deflection through the galvanometer is reduced to half of its initial value $\left(=\frac{\theta}{2}\right)$ then

$$I'_g = k\left(\frac{\theta}{2}\right) = \frac{ES}{R(G+S)+GS}$$

On dividing equation (E 6.2) by the equation (E 6.8),

$$\frac{I_g}{I'_g} = \frac{E}{R+G} \times \frac{R(G+S)+GS}{ES} = 2$$

or, $R\,(G + S) + GS = 2S\,(R + G)$

$\Rightarrow$ $RG = RS + GS$

$\Rightarrow$ $G\,(R - S) = RS$

or, $$G = \frac{RS}{R-S} \qquad \text{(E 6.9)}$$

By knowing the values of R and S, the galvanometer resistance G can be determined. Normally R is chosen very high (~ 10 kΩ) for which,

$$G \simeq S$$

The figure of merit *(k)* of the galvanometer is defined as the current required for deflecting the pointer by one division. That is,

$$k = \frac{I}{\theta} \qquad \text{(E6.10)}$$

For determining the figure of merit of the galvanometer the key K_2 is opened in the circuit arrangement.

Using equations (E 6.2) and (E 6.3) the figure of merit of the galvanometer is given by,

5_XII_Experiment_6_7 Folder.indd 116 05-10-2018 12:38:07

$$k = \frac{1}{\theta}\left(\frac{E}{R+G}\right) \qquad \text{(E 6.11)}$$

By knowing the values of E, R, G and θ the figure of merit of the galvanometer can be calculated.

PROCEDURE

1. Clean the connecting wires with sand paper and make neat and tight connections as per the circuit diagram (Fig. E 6.1).
2. From the high resistance box ($R_{BOX\ 1}$) (1–10 kΩ), apply 5 kΩ key and then close the key K_1. Adjust the resistance R from this resistance box to get full scale deflection on the galvanometer dial. Record the values of resistance R and deflection θ.
3. Insert the key K_2 and keep R fixed. Adjust the value of shunt resistance S to get the deflection in the galvanometer which is exactly half of θ. Note down S. Remove plug K_2 after noting down the value of shunt resistance S.
4. Take five sets of observations by repeating Steps 2 and 3 so that θ is even number of divisions and record the observations for R, S, θ and $\frac{\theta}{2}$ in Table E 6.1.
5. Calculate the galvanometer resistance G and figure of merit k of galvanometer using equations (E 6.9) and (E 6.11) respectively.

OBSERVATIONS

Emf of the battery E = ... V

Number of divisions on full scale of galvanometer = ...

Table E 6.1: Resistance of galvanometer

Sl. No.	High Resistance R (Ω)	Deflection in the galvanometer θ (divisions)	Shunt resistance S (Ω)	Half deflection in the galvanometer $\frac{\theta}{2}$ (divisions)	$G = \frac{R.S}{R-S}$ (Ω)	$k = \frac{E}{R+G}.\frac{1}{\theta}$ A/divisions
1.						
2.						
--						
5.						

5_XII_Experiment_6_7 Folder.indd 117 05-10-2018 12:38:08

CALCULATIONS

Mean value of G (resistance of galvanometer) = ... Ω

Mean value of k figure of merit of galvanometer) = ... ampere/division.

RESULT

1. Resistance of galvanometer by half deflection method, G = ... Ω
2. Figure of merit of galvanometer, k = ...ampere/division

PRECAUTIONS

1. Key K_1 should be inserted only after high value of R has been applied from resistance box otherwise galvanometer coil may burn.
2. Adjust R such that deflection in galvanometer is of even division so that $\theta/2$ is more conveniently obtained.
3. Emf of the battery should be constant.
4. Use as high values of R as practically possible. This ensures correct value of G.
5. All the connections should be tight.

5_XII_Experiment_6_7 Folder.indd 118 05-10-2018 12:38:08

EXPERIMENT 7

AIM

To convert the given galvanometer (of known resistance and figure of merit) into (i) an ammeter of a desired range (say 0 to 30 mA) and (ii) a voltmeter of desired range (say 0 to 3 V) and to verify the same.

APPARATUS AND MATERIAL REQUIRED

A galvanometer of known resistance and figure of merit, a constantan or manganin wire of 26 or 30 SWG, a battery or a battery eliminator, one way key, a rheostat of range 200 Ω, a multimeter, connecting wires and sand paper.

I PRINCIPLE (CONVERSION OF GALVANOMETER INTO AN AMMETER)

A galvanometer is a sensitive device which can detect the presence of very small current in a circuit of the order of 100 mA. For measuring current of the order of an ampere, a low resistance called shunt resistance *S*, is connected in parallel across the galvanometer having resistance *G*.

If I_0 is the total current in the circuit for full scale deflection, then the current $(I_0 - I_g)$ passes through *S*, where I_g is current that flows through the galvanometer for full scale deflection. The instrument is calibrated so as to read the current directly in ampere and then it can be used as an ammeter. Since *G* and *S* are parallel to each other therefore, the potential difference across both are same, hence,

$$I_g G = \left(I_0 - I_g\right) S \qquad \text{(E 7.1)}$$

or

$$S = \frac{I_g G}{I_0 - I_g} \qquad \text{(E 7.2)}$$

The figure of merit of the galvanometer is represented by the symbol *k* which represents the current corresponding to one scale division; thus if *N* is the total number of divisions (on either side) of the galvanometer scale, the value of current I_g is given by

$$I_g = kN$$

If n represents the actual deflection in the converted galvanometer, then the total current will be,

$$I = n\frac{I_O}{N}.$$

PROCEDURE

1. Determine the galvanometer resistance G and figure of merit k *as per the procedure given in Experiment 6.* (These values may be taken form Experiment 6)
2. Note the total number of divisions N on either side of zero of the galvanometer scale.
3. Calculate the current I_g for full scale deflection in the galvanometer by using the relation $I_g = Nk$, where k is the figure of merit of the galvanometer.
4. Calculate the shunt resistance S using the formula $S = \frac{I_g G}{I_O - I_g}$. [$I_o$ is the range (say 0–30mA) to which galvanometer is desired to be converted].
5. Measure the radius r of the wire at different locations and from the given value of the specific resistance ρ, calculate the length of the wire l, for resistance S [use the formula $l = \frac{S\pi r^2}{\rho}$].
6. Let the calculated length of the wire be 10 cm. Then cut 3–4 cm extra length and put it in parallel with the galvanometer and complete the circuit as shown in Fig. E 7.1.

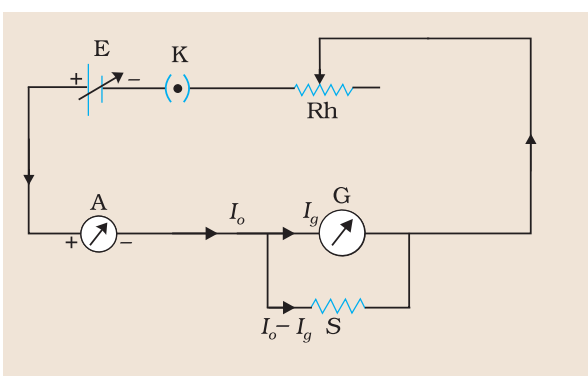


Fig. E 7.1: *Circuit to verify conversion of galvanometer into an ammeter*

7. Adjust the length of the wire so that when we see full scale deflection in the galvanometer, the current in the ammeter (multimeter used as an ammeter) is 30 mA.
8. Thus, the galvanometer is now converted into an ammeter whose range is 0–30 mA.

5_XII_Experiment_6_7 Folder.indd 120 05-10-2018 12:38:08

9. Now measure the exact length of the shunt wire and calculate its resistance by using the previously measured value of radius and the known value of specific resistance.

10. Compare the above value of resistance to the one calculated in Step 4.

OBSERVATIONS

1. Galvanometer resistance, G (given) = ... Ω

2. Figure of merit of the galvanometer, k (given) = ... ampere/division

3. Number of divisions on either side of zero of the galvanometer scale, N = ... division

4. Current required for producing full scale deflection of N divisions, $I_g = k\,N$ = ... ampere

5. Radius of wire:

   Least count of the given screw gauge = ... cm

   Zero error = ... cm

   Zero correction = ... cm

   Observed diameter of the wire:

   (i) ... cm (ii) ... cm

   (iii) ... cm (iv) ... cm

   Mean observed diameter, D = ... cm

   Radius of the wire $r = D/2$ = ... cm

CALCULATIONS

1. Shunt resistance = $S = \dfrac{I_g G}{I_0 - I_g}$ = ... Ω

2. Given value of specific resistance of the material of the wire ρ = ... Ω m

5_XII_Experiment_6_7 Folder.indd 121 05-10-2018 12:38:08

3. Required length of the wire, $l = \frac{S\pi r^2}{\rho}$ = ... cm

4. Observed length of the shunt wire for the desired range, l' = ... cm

5. Shunt resistance from the observed length of the wire, $S' = \frac{l' \times \rho}{\pi r^2}$ = ... Ω

RESULT

To convert the given galvanometer into an ammeter of the range, 0 to ... ampere

1. the calculated resistance of the shunt wire, S = ... Ω
2. the observed resistance of the shunt wire, S' = ... Ω

PRECAUTIONS

1. Use appropriate range of digital multimeter.
2. Cut about 3 to 4 cm extra length over the calculated length of the wire.
3. After adjusting the length of the wire, measure the length of the wire between the two plugs carefully.

II PRINCIPLE (CONVERSION OF GALVANOMETER INTO A VOLTMETER)

By connecting a high resistance of suitable value in series with a galvanometer, it is converted into a voltmeter. Voltmeter is always connected in parallel with the electrical component across which potential difference is to be measured.

If a galvanometer (having resistance G) shows a full scale deflection for a maximum current I_g, the potential difference across the galvanometer is I_gG. If the converted galvanometer is desired to have a range V_o volt, then the resistance to be joined in series with galvanometer, is given by $R = \frac{V_0}{I_g} - G$.

5_XII_Experiment_6_7 Folder.indd 122 05-10-2018 12:38:08

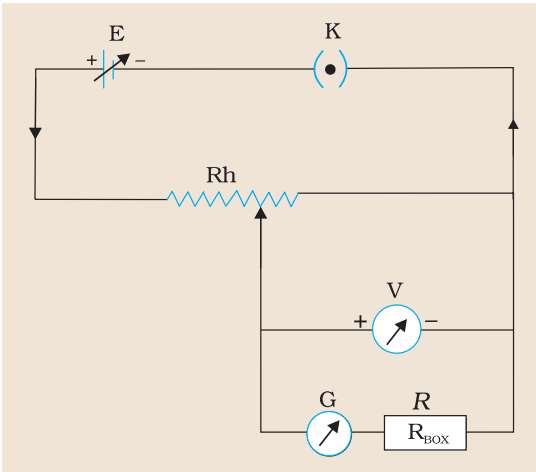


Fig. E 7.2: *Circuit to verify conversion of galvanometer into a voltmeter*

PROCEDURE

1. Calculate the value of the series resistance R for given values of V_0, I_g and G.

2. Make the connections as shown in Fig. E 7.2 by connecting a cell and converted galvanometer and a multimeter used as a voltmeter in same range in parallel, with a high resistance rheostat Rh.

3. Close the key K and adjust the rheostat so that the voltage shown in the voltmeter is equal to the desired range (say 3 V). Simultaneously, adjust the position of the slider of the rheostat and also the resistance from the resistance box so that when full scale deflection is observed on the galvanometer, the voltmeter shows 3 V. Note the total resistance from the resistance box.

OBSERVATIONS

1. Resistance of the galvanometer, G (given) = ... Ω
2. The figure of merit of the galvanometer, k (given) = ... ampere/division
3. Number of divisions on either side of zero of the galvanometer scale, N = ... division
4. Current required for producing full scale deflection of N divisions, $I_g = k\,N$ = ... ampere
5. Total resistance applied from the resistance box = ... Ω

CALCULATIONS

Resistance to be connected in series with the galvanometer,

$$R = \frac{V_0}{I_g} - G = \ldots \Omega$$

5_XII_Experiment_6_7 Folder.indd 123 05-10-2018 12:38:08

RESULT

To convert the given galvanometer into a voltmeter of the range, 0 to ... V

1. The value of the calculated series resistance, R = ...Ω
2. The value of the observed series resistance, R' = ...Ω
3. Current for full scale deflection, I_g = ...ampere

PRECAUTIONS

1. The resistance box used should be of high resistance.
2. The rheostat should be used as potential divider.
3. High resistance of the order of 10 kΩ from the resistance box should be applied first and then the battery key should be closed to avoid any damage to the galvanometer.

SUGGESTED ADDITIONAL EXPERIMENTS/ ACTIVITIES

1. Calculate the length of the wire of same material if the radius is doubled.
2. Calculate the length of the wire if the radius is same but material used is copper.
3. Change the range of ammeter and voltmeter and repeat the same procedure as followed in the above experiment.
4. Use the converted ammeter/voltmeter for verification which has the same range as the range of conversion.

5_XII_Experiment_6_7 Folder.indd 124 05-10-2018 12:38:08

EXPERIMENT 8

AIM

To determine the frequency of alternating current using a sonometer.

APPARATUS AND MATERIAL REQUIRED

A sonometer with a non-magnetic wire of 26 SWG (e.g., brass wire) stretched over it, a horse-shoe magnet, 0-6V ac source (battery eliminator), slotted 50g weights with hanger, two knife edge wedges, rheostat, crocodile clips, laboratory stand and connecting wires.

DESCRIPTION OF APPARATUS

Sonometer

For the kit, the size of the sonometer has been reduced from 1m to 0.5m, all other features remaining the same. To obtain resonating length of the sonometer wire in measurable limits the tension is also provided by hanging masses in the range of 100g–300g.

To set up the apparatus cut about 1m length of (non-magenetic brass) wire. One end of the wire is to be fixed near one edge of the sonometer and the other is passed over the pulley. A hanger weight is attached to this end. Make sure that the fixed end of the wire is in line with the pulley and the wire is suspended freely from the pulley.

Remove the kinks, if any, on the wire before fixing it. To do so hold the wire firmly with a double folded piece of paper or cloth and move it along the entire length of wire.

PRINCIPLE

The frequency n of the fundamental mode of vibration of a stretched string, fixed at two ends, is given by

$$n = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Here l is the length of the vibrating string, T is the tension in the string and m is its mass per unit length.

If an alternating current is passed through the sonometer wire, it produces an alternating magnetic field around it. Due to interaction between the magnetic field produced by the current carrying wire and the magnetic field due to horse shoe magnet, the wire starts vibrating with the frequency of applied alternating current.

When the fundamental frequency of the stretched sonometer wire becomes equal to the frequency of the alternating current passing through it, resonance occurs and sonometer wire vibrates with maximum amplitude. Hence, if f is the frequency of the alternating current, then

$$f = n = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

$$4n^2 l^2 m = T$$

or

$$l^2 = \frac{1}{4n^2 m} \times T$$

A graph between T (taken on x-axis), and l^2 (taken on y-axis), would be a straight line. The slope of this straight line would be

$\frac{1}{4n^2 m}$, so that

$$n^2 = \frac{1}{4m \times slope}$$

$$n = \frac{1}{2}\frac{1}{\sqrt{m \times slope}}$$

The frequency of alternating current, f (= n) can be determined using the value of the slope.

PROCEDURE

1. Set up the sonometer and stretch the wire AB by placing a load of 300 g on the hanger. Place two wedges W_1 and W_2 under the stretched wire. To begin with keep the wedges at maximum separation. (Fig. E 8.1)
2. Put the horse-shoe magnet near the middle of the sonometer box in such a way that the wire lies in between its poles.

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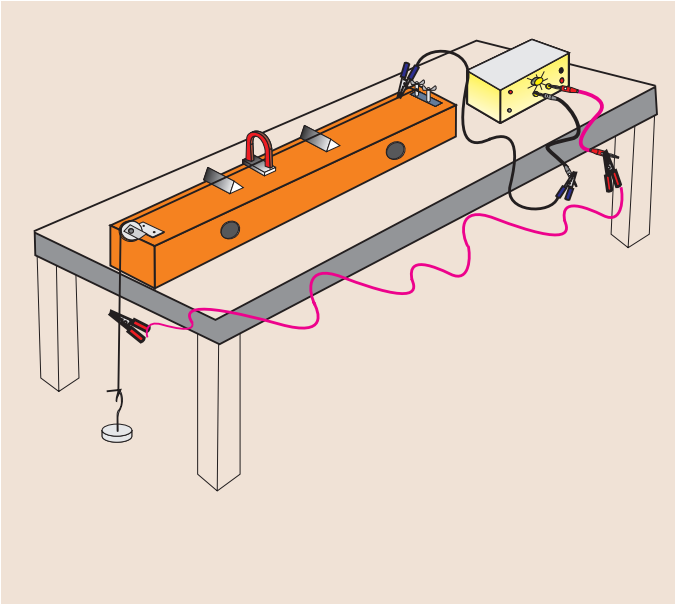

Fig. E 8.1: *Set up for finding frequency of ac mains using a sonometer*

Make sure that the sonometer wire is perpendicular to the magnetic field. Connect the ends of the wire, with crocodile clips to the given ac source (battery eliminator).

3. Switch on the alternating current supply and adjust the length of vibrating portion of AB by sliding the wedge W_1 and W_2. Make this adjustment until the amplitude of the vibrating string is maximum.
4. Note the position of the wedges with the help of scale fixed on the side of the sonometer box. The difference between these two readings gives us the vibrating length, also note the tension in the string.
5. Decrease the load in steps of 50g from inital starting load of 250 g and each time find the vibrating length.
6. Find the mass of a known length of sonometer wire to compute its mass per unit length. Alternatively mass per unit length may be found from a standard table.

OBSERVATIONS

1. Mass per unit length, m = ... g/cm = ...kg/m
2. Acceleration due to gravity, g = ...ms^{-2}

Table E 8.1: Resonant length

S. No.	Load *(M)* including mass of hanger (kg)	Tension $T = mg$ (N)	Resonant length l			Mean l *in* (m)	$n = \frac{1}{2l}\sqrt{\frac{T}{m}}$ (Hz)
			First trial (m)	Second trial (m)	Mean (m)		
1.							
2.							
3.							
4.							
						Mean	

6_XII_Experiment_8_9 Folder.indd 127 05-10-2018 12:51:39

CALCULATIONS

1. For each set, calculate the value of n using the formula given above. Find the mean of these values.
2. Plot a graph of l^2 against T with l^2 on y-axis and T on x-axis. Determine the slope of the graph. Using the value of the slope determine the frequency of alternating current using the given formula.

RESULT

1. The graph between T and l^2 is a straight line.
2. Slope of the graph = $\frac{1}{4mn^2}$ = ...
3. Frequency of ac supply $f = n$

   (i) from calculation ...Hz

   ii) from graph ...Hz

PRECAUTIONS

1. The magnet poles should be close to the middle of the sonometer wire.
2. After taking each of the observations, circuit should be switched off for a few minutes.
3. This experiments should preferably be performed at 2V ac.

6_XII_Experiment_8_9 Folder.indd 128 05-10-2018 12:51:39

EXPERIMENT 9

AIM

To find image distance (v) for different values of object distance (u) for a given concave mirror and to calculate its focal length.

APPARATUS AND MATERIAL REQUIRED

Improvised optical bench assembly, two sharp-edged needles (pencils of two different colours with sharp tip), concave mirror of less than 20 cm focal length, three uprights (with sliding bases), a ground glass screen and spirit level.

PROCEDURE

1. **Determination of rough focal length**

   Determine the rough focal length of the given concave mirror. For this you will require the concave mirror, screen and a scale.

   (i) Stand in shade facing a brightly lit distant object. The distant object could be a building, tree or any other object in sun light.

   (ii) Hold the mirror in your one hand and screen in the other hand. Point the mirror towards the selected object and place the screen in front of the mirror.

   Move the mirror in forward or backward direction till you obtain a sharp image of the selected object on the screen. You may have to tilt the mirror to get the image on the screen.

   Measure the distance between the mirror and screen. This will give you the rough focal length of the concave mirror.

2. Set up the optical bench as explained in Appendix 1. Make sure that the bench is horizontal (levelled).

3. **Removing parallax**

   To understand what is parallax, do the following activity. Stretch index finger of one hand in vertical position and place the index

finger of the other hand just above it in an inverted position . Move your head to left and then to right while keeping your eyes on the tip of the two fingers. What do you observe? Do you find both fingers moving together whether you move your head to the left or to the right?

Now, place one of the index fingers behind the other such that there is a gap of 5–6 cm between them. Move your head from one side to the other while observing the two fingers. Do you notice that the nearby finger changes its position with respect to the second finger as you move your head from one side to the other. We say that there is a parallax between the two fingers when they are not coinciding with each other. In the earlier case when one finger was placed just above the other, i.e., there was no parallax between them the two fingers appeared to move together when you moved your head, so we can locate the position of the real image of an object by just bringing another similar object as close to it as possible so that no parallax appears between the two.

4. **Optical Alignment**

   (i) Match the centre markings on the upright holder with sliding base for each holder.

   (ii) Adjust the height of the object and image (pencil tips) to align them with the centre of the mirror.

   (iii) Fix the concave mirror mount near either end of the scale assembly (optical bench).

   (iv) Consider one of the pencils as object. (Slide the object pencil, say P_1, away from the mirror and place it at such a distance so that a sharp and inverted image is formed above itself). This distance of object image from the mirror is nearly two times the focal length, i.e., 2f.

5. Now place P_1 anywhere between F and C.

6. Locate the image of P_1 using the other pencil P_2 as shown in Fig. E 9.1. Remember that parallax has to be removed between the image of the object pencil P_1 and pencil P_2.

7. Note the positions of object pencil P_1, and its image with the help of pencil P_2 and the mirror on the optical bench.

8. The distance between the mirror and the object pencil P_1, is u and that between image pencil P_2 and mirror is v.

9. Repeat the experiment for at least five different positions of the object and determine the corresponding values of v. Record your observations in the tabular form.

6_XII_Experiment_8_9 Folder.indd 130 05-10-2018 12:51:39

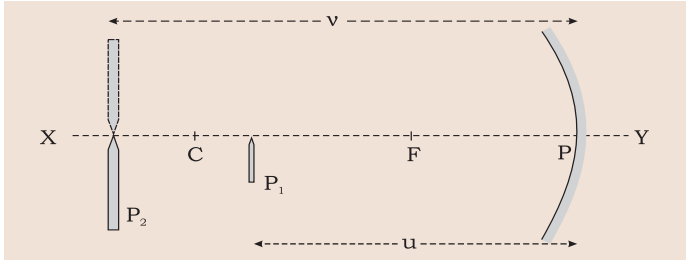

Fig. 9.1: *Ray diagram for finding focal length of a concave mirror*

OBSERVATIONS

Rough focal length of the concave mirror = ...cm

Table E 9.1: Determination of *u*, *v* and *f*

Sl. No.	Position of the mirror M (cm)	Corrected $u = P_1 - M$ (cm)	Corrected $v = P_2 - M$ (cm)	$f = \frac{uv}{u \times v}$ (cm)	Δf (cm)
1.					
2.					
--					
6.					
			Mean		

CALCULATIONS

Determine the values of u and v, compute the value of f in each case. Tabulate them and find the mean value of the focal length of the given concave mirror. Also compute Δf for each observation using the formula given below. Follow sign convention to assign +ve and –ve values to u and v.

Calculation of Error

$$\because \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{\Delta f}{f^2} = \frac{\Delta u}{u^2} + \frac{\Delta v}{v^2}$$

$$or\ \Delta f = f^2\left[\frac{\Delta u}{u^2} + \frac{\Delta v}{v^2}\right]$$

6_XII_Experiment_8_9 Folder.indd 131 05-10-2018 12:51:39

RESULT

The focal length of the given concave (converging) mirror is $(f \pm \Delta f) = \ldots \pm \ldots$cm

Here, f denotes mean value of the focal length and Δf is maximum of the six values of the error.

PRECAUTIONS

1. The uprights supporting the object and image pencils, and the mirror should be rigid and mounted vertically.
2. The object pencil should be kept in between the centre of curvature and the focus of the mirror.
3. Eye should be placed at a distance of distinct vision (25 cm) from the image pencil.
4. It should be ensured while removing the parallax that the tip of the inverted image of the object pencil touches the tip of the image pencil and do not overlap.
5. Image of the Sun should not be seen directly as it may hurt your eyes.
6. Always keep your eyes at a safe distance from the sharp tip of the object and image pencils while image formation and parallax removal.

6_XII_Experiment_8_9 Folder.indd 132 05-10-2018 12:51:39

EXPERIMENT 10

AIM

To find the focal length of a convex lens by plotting graphs between u and v or between $1/u$ and $1/v$.

APPARATUS AND MATERIAL REQUIRED

Improvised optical bench assembly, two sharp-edged pencils of two different colours with sharp tip, convex lens of less than 20cm focal length, three uprights (with sliding bases), metre scale and a screen.

PROCEDURE

1. Determine the rough focal length f, of the given convex lens following the steps suggested for concave mirror in Experiment 9. However, here the screen should be placed on the other side of the lens. Once a distinct image of a distant object is obtained on the screen measure the distance between the lens and the image with a scale. This distance is a rough estimate of the focal length, f of the convex lens.

Note: Do not look at the image of the sun directly as it may harm your eyes.

2. Assemble the optical bench on a rigid table or on a platform. Make optical bench horizontal using a spirit level. Follow as explained in Appendix 1 and make necessary adjustment if needed.

3. Clamp the convex lens on a upright and mount it vertically almost near to the middle of the optical bench such that its principal axis is parallel to the optical bench. In this position, the lens would lie in a plane perpendicular to the optical bench.

4. Place the vertically mounted sharp pencils P_1 and P_2 of different colours on left and right hand sides of the lens respectively. Adjust the pencils P_1 and P_2 so that the heights of their tips become equal to the height of the optical centre O of the lens.

Let the pencil P_1 (placed on left hand side of the lens) be the object and the pencil P_2 (lying on right hand side) be the image pencil.

5. Displace the object pencil P_1 (on left side of the lens) to a distance slightly less than $2f$ from the optical centre O of the lens. Locate the position of the real and inverted image on the other side of the lens above the image pencil P_2.

6. Using the method of parallax, adjust the position of the image pencil P_2 such that the inverted image of the object pencil P_1 coincides with the image pencil P_2 (Fig. E 10.1).

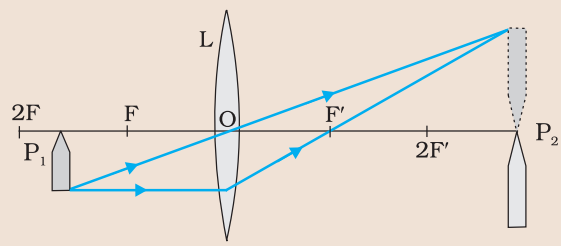

Fig. E 10.1: *The ray diagram for finding the focal length of a convex lens*

Note: As the value of u changes from $2f$ to f, v changes from $2f$ to infinity. Since the values of u and v are interchangeable, i.e., the object and image are two conjugate points. For a position of the object pencil over the range $2f$ to f, position of image lies between $2f$ and infinity. It is therefore clear that complete range of values are obtained for both u and v.

7. Note the upright position of the object pencil P_1, convex lens and image pencil P_2 on the optical bench and record the readings in an observation table.

8. Move the object pencil P_1 closer to the optical centre O of the lens (say by 2 cm or 3cm). Repeat the experiment and record at least 6 sets of readings for various distances of object pin between f and $2f$ from the lens.

OBSERVATIONS

Approximate focal length of the convex lens = ... cm

7_XII_Experiment_10 Folder.indd 134 04-10-2018 17:12:49

Table E 10.1: Determination of *u*, *v* and *f*

S. No.	Position of lens upright a (cm)	Position of object pencil upright b (cm)	Position of image pencil upright c (cm)	$u = a - b$ (cm)	$v = a - c$ (cm)	$\frac{1}{u}$ cm^{-1}	$\frac{1}{v}$ cm^{-1}	$f = \frac{uv}{u+v}$ cm	Δf (cm)
1.									
2.									
--									
6.									
						Mean			

CALCULATIONS

A. Determine values of u and v and compute the value of f using lens formula. Tabulate them in the table and find the mean value of the focal length of the given convex lens.

Note: According to new Cartesian sign convention u is negative.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

or $$\frac{\Delta f}{f^2} = \frac{\Delta u}{u^2} + \frac{\Delta v}{v^2}$$

$$\Delta f = f^2 \left[\frac{\Delta u}{u^2} + \frac{\Delta v}{v^2} \right]$$

Where Δu and Δv are the least count of scale on the optical bench which in this case is 0.1cm, i.e., $\Delta u = \Delta v = 0.1$ cm.

Maximum of 6 values of Δf is to be reported with the result as the experimental error.

CALCULATION OF FOCAL LENGTH BY PLOTTING GRAPHS

u – v Graph: Take u along x-axis and v along y-axis. Scales of x- and y-axis should be same. Draw a hyperbola curve for various values of u and v (Fig. E 10.2). Note that 6 sets of readings for u

7_XII_Experiment_10 Folder.indd 135 04-10-2018 17:12:49

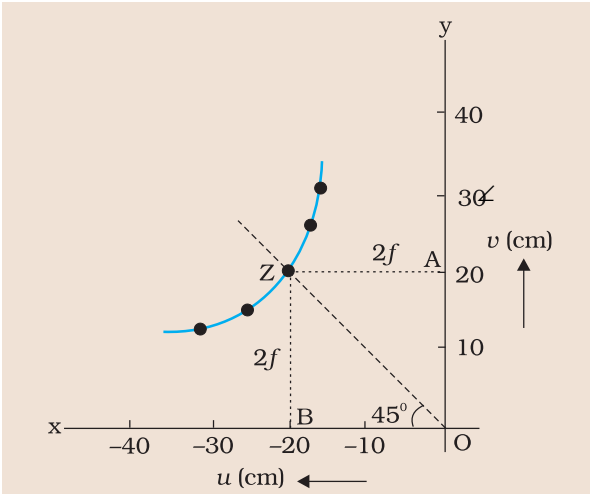

Fig. E 10.2: *u versus v graph for convex lens*

between f and $2f$, give you 12 points on the graph by interchanging values of u and v.

Draw a line through point 'O' bisecting the angle XOY which intersects the u-v curve (Fig. E 10.2) at point Z. At this point Z note that u=2f; v=2f. Draw two lines AZ and BZ perpendicular to y- and x-axis, respectively. The lengths AZ and BZ are both equal to distance 2f. Thus by plotting the $u - v$ graph, the focal length of the lens can be obtained.

Distance OA (= 2f) on y-axis = ... cm

Distance OB (= 2f) on x-axis = ... cm

Mean focal length of the convex lens, f

$$= \frac{OA + OB}{4} = \ldots \text{ cm}$$

1/u – 1/v graph: Draw a straight line graph by plotting 1/u along the x-axis and 1/v along the y-axis (Fig. E 10.3). Both the intercepts OA′ (on y-axis) and OB′ (on x-axis) will be equal to distance 1/f.

Intercept OA′ (= 1/f) on y-axis =...cm^{-1}

Intercept OB′ (= 1/f) on x-axis =...cm^{-1}

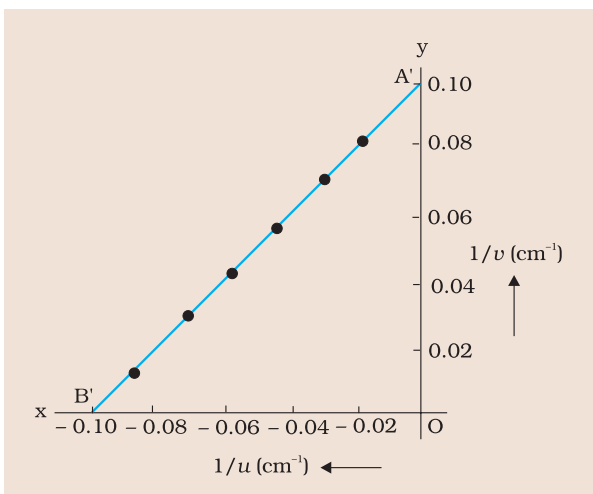

Fig. E 10.3: *1/u versus 1/v graph for a convex lens (not to scale)*

Mean focal length (f) of the convex lens = $\frac{2}{OA' + OB'}$ =...cm.

RESULT

The focal length of the given converging thin convex lens:

(i) From calculations as shown in Observation Table E10.1 $f \pm \Delta f$ = ...cm (here f is mean value of the focal length)

(ii) From $u - v$ graph =...cm, and

(iii) From 1/u – 1/v graph =...cm.

7_XII_Experiment_10 Folder.indd 136 04-10-2018 17:12:49

PRECAUTIONS

1. The uprights supporting the lens, object and image pencils should be rigid and mounted vertically.
2. Eye should be placed at a distance more than 25 cm from the image pencil.
3. An error may arise in the observations if optical bench is not horizontal and similarly if the tips of pencils and optical centre of the lens are not at the same horizontal level.
4. The tip of the inverted image of the object pencil must touch the tip of the image pencil and must not overlap. This should be ensured while removing the parallax.
5. Care should be taken while taking observations that sharp tip of the pencils do not injure eyes.

7_XII_Experiment_10 Folder.indd 137 04-10-2018 17:12:49

EXPERIMENT 11

AIM

To find the focal length of a convex mirror using a convex lens.

APPARATUS AND MATERIAL REQUIRED

Improvised optical bench assembly with uprights for holding lens, mirror and two needles (pencils of two different colours with sharp tip), a thin convex lens, a convex mirror, a metre scale and white screen.

PROCEDURE

1. In case, if the focal length of the given thin convex lens is not known then approximate value of its focal length should be estimated first, following the steps as suggested in Experiment–10.

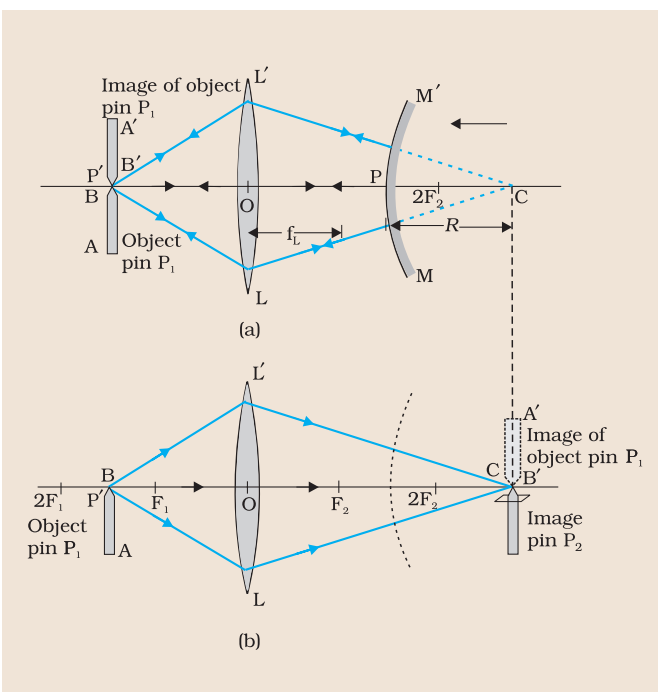

Fig. E 11.1: *(a) Image A'B' formed by the convex mirror and convex lens, image A'B' concides with the object A B at P' (b) image formed by convex lens is inverted and magnified.*

2. Assemble the improvised optical bench, following the steps as suggested in Experiment 9 and place it on a rigid table or on a platform horizontally.

3. Place the uprights mounted with pencil P_1 (object pencil), convex lens LL', and convex mirror MM' on the horizontal optical bench.

4. Check that the lens, mirror, and pencil P_1 are vertically placed on the optical bench. Also ensure that the tip of the pencil, optical centre O of the convex lens LL', and pole P of the convex mirror MM' lie on the same horizontal straight line, parallel to the optical bench.

5. Place the object pencil P_1 from the convex lens LL' at a distance slightly greater than the focal length of the lens.
6. Adjust the position of the convex mirror MM' till you obtain a real and inverted image coinciding with the object pencil P_1, as shown in Fig E 11.1(a).
7. Note the position of uprights holding the object pencil P_1, convex lens LL', and convex mirror MM' and record the observations in the observation table E 11.1.
8. Remove the convex mirror from its uprights and fix image pencil P_2 on it. Adjust the height of pencil such that its tip also lies on principal axis of the lens.
9. Using the method of parallax and without changing the position of lens LL' and object pencil P_1, adjust the position of image pencil P_2 on the other side of the lens so that it coincides with the real and inverted image of the object pencil P_1 formed by the convex lens [Fig. E 11.1(b)]. Note the position of the image pencil.
10. Repeat the steps 6 to 9 by changing the separation between the pencil P_1 and lens LL' and the mirror MM'. In this manner, take 5 sets of observations.

OBSERVATIONS

Focal length of the convex lens, f (estimated/given) = ... cm

CALCULATIONS

Table E 11.1: Determination of radius of curvature of convex mirror, *R*

S. No.	Upright position of				$R = c - d$ (cm)	Focal length $f = \frac{R}{2}$ (cm)
	Object pencil P_1 a (cm)	Convex lens LL' b (cm)	Convex mirror MM' c (cm)	Image pencil P_2 d (cm)		
1.						
2.						
--						
6.						
					Mean	

8_XII_Experiment_11_13 Folder.indd 139 04-10-2018 17:13:23

Calculate the mean value of radius of curvature of the convex mirror, R, and determine its focal length using the following relation

$$f = \frac{R}{2} = \ldots \text{ cm}$$

RESULT

The focal length of the given convex mirror is $f = \ldots$ cm.

Here, f is mean value of the focal length.

PRECAUTIONS

1. The uprights supporting the pencils, lens and mirror must be rigid and mounted vertically.
2. Eye should be placed at a distance of about 25 cm or more from the image pencil.
3. Optical bench should be horizontal. The tips of pencils, optical centre of convex lens and pole of the mirror should be at the same horizontal level.
4. While taking observations, utmost care should be taken against damage to eyes by sharp tips of pencils and other such objects.

8_XII_Experiment_11_13 Folder.indd 140 04-10-2018 17:13:23

EXPERIMENT 12

AIM

To find the focal length of a concave lens with the help of a convex lens.

APPARATUS AND MATERIAL REQUIRED

Improvised optical bench assembly with uprights for holding the lenses and two pencils of different colours with sharp tips, a thin concave lens, a convex lens of focal length (~15cm) smaller than that of the concave lens, a metre scale and a spirit level.

PROCEDURE

1. In case, the focal length of the given thin convex lens is not known the rough value of its focal length (f_L) should be estimated first to ensure that its focal length is less than that of the concave lens, follow the steps as suggested in Experiment 10.
2. Assemble the improvised optical bench, following the steps as suggested in Appendix 1 and place it on a rigid platform.
3. Place the uprights mounted with pencil P_1 (object pencil), convex lens L_1, and another pencil P_2 (image pencil) on the optical bench.

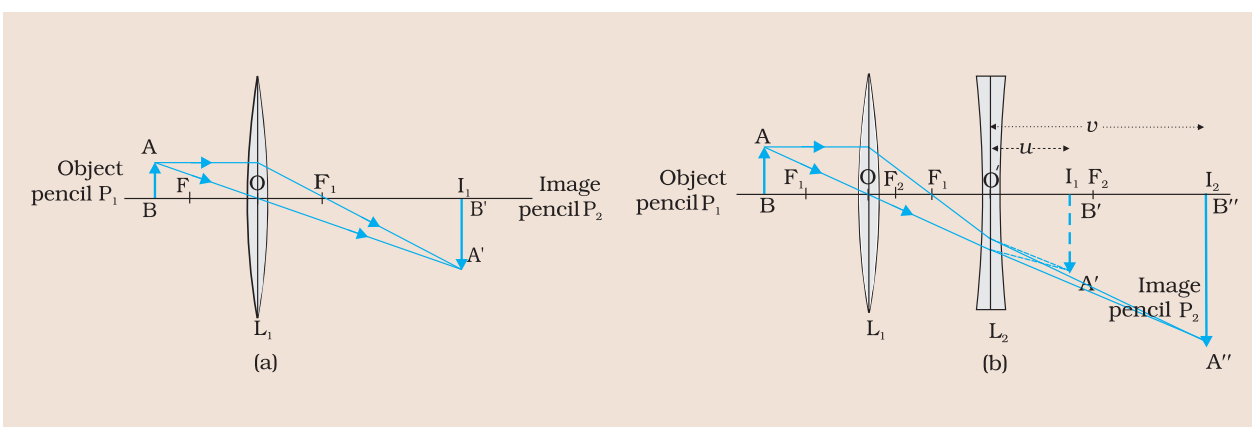

Fig. E 12.1: *Formation of image (a) by a convex lens; and (b) by a combination of convex lens and concave lens*

4. Check the collinearity of the object pencil tip P_1, optical centre O of convex lens L_1, and the tip of image pencil P_2 along a horizontal straight line which is parallel to the length of the optical bench. In this condition the planes of lens and both the pencils would be perpendicular to the axis of the lens.

5. Place the object pencil P_1 from the convex lens at a distance slightly greater than the focal length f_L of the lens.

6. Locate its real and inverted image at point I_1 on the other side of the lens by removing parallax between the image pencil P_2 and image of the object pencil P_1 [Fig. E 12.2 a].

7. Read the positions of the uprights holding the object pencil P_1, convex lens L_1, and image pencil P_2 (i.e., point I_1). Record these observations in Table E 12.1.

8. From now on, do not change the position of the convex lens L_1 and the position of the object pencil P_1. Insert the concave lens L_2, in between the convex lens L_1 and image pencil P_2. Now the image of object pencil P_1 will shift further from the convex lens L_1, to a point I_2 (say). Adjust the position of the concave lens so that the point I_2 is sufficiently away from the point I_1.

9. In case the image formed by the combination of convex and concave lenses is not distinctly visible, try to see it on moving the concave lens nearer to the point I_1 and to locate the image by using a pencil held in hand, and keeping the image pencil P_2 at point I_1 as a guide to decide which way to shift the concave lens L_2. After having seen the clear image at point I_2 and ensure that it lies within the range of the optical bench, move image pencil P_2 to locate the image (or point I_2) more accurately using

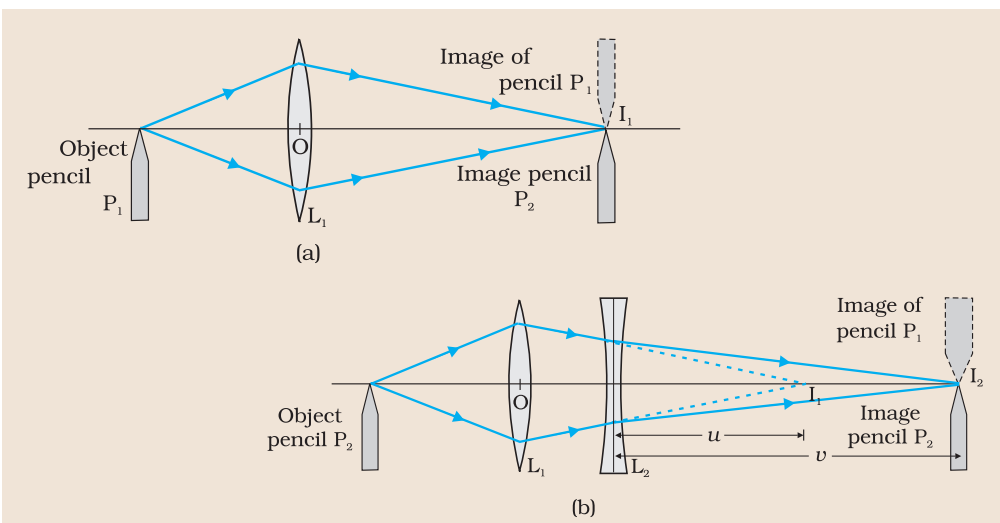

Fig. E 12.2: *Focal length of concave lens with the help of convex lens*

8_XII_Experiment_11_13 Folder.indd 142 04-10-2018 17:13:23

the method of parallax [Fig E 12.2 b]. Since the image forming at I_2 is quite enlarged, it can be blurred.

10. Note the positions of uprights holding the concave lens and image pencil P_2, i.e., point I_2. Note the readings in the observation Table.

11. Change the position of upright holding the object pencil P_1 and repeat the steps 5 to 10. Take five sets of observations.

OBSERVATIONS

Focal length of the convex lens, f = ... cm

Table E 12.1: Determination of *u*, *v*, and *f* of concave lens

S. No.	Position of								
	Object pencil upright P1, a (cm)	Convex lens L_1 upright, b (cm)	Image formed by L_1, point I1, c (cm)	Concave lens L2 upright, d (cm)	Image formed by L1 and L2, point I2, g (cm)	u = c – d (cm)	v = g – d (cm)	f = uv/(u – v) (cm)	Δ f (cm)
1.									
2.									
--									
5.									
								Mean	

CALCULATIONS

Find the focal length of the concave lens using the formula $f = \dfrac{uv}{u - v}$

Error

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{\Delta f}{f^2} = \frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}$$

$$\Delta f = f^2 \left[\frac{\Delta v}{v^2} + \frac{\Delta u}{u^2} \right]$$

8_XII_Experiment_11_13 Folder.indd 143 04-10-2018 17:13:24

Where, Δu, Δv represent least counts of the measuring scale. Values of u, v, f are to be taken from the Observation Table. Maximum of the five values of the error Δf is to be reported with the result as error.

RESULT

The focal length of the given concave lens is $(f \pm \Delta f)$ = ... ± ...cm.

Here, f is mean value of the focal length.

PRECAUTIONS

1. The concave lens must be placed near the convex lens. In fact, the second image I_2 is formed only when the distance between concave lens L_2 and first image I_1 (which acts as virtual object for the concave lens) is less than the focal length of the concave lens.
2. Since the image formed at I_2 is quite enlarged, it can be blurred. Therefore, it would be preferable to use a thin and sharp object pin and shine it with the light using a lighted electric bulb.
3. The convex lens and the pin P_1 must not be disturbed during the second part of the experiment.
4. A diminished, real and inverted image of the image pin P_2 might also be formed by the light rays reflecting from the concave surface of the lens L_2. It should not be confused with the bold and bright image formed by the combination of convex and concave lenses.

8_XII_Experiment_11_13 Folder.indd 144 04-10-2018 17:13:24

EXPERIMENT 13

AIM

To determine the angle of minimum deviation for a given glass prism by plotting a graph between the angle of incidence and the angle of deviation.

APPARATUS AND MATERIAL REQUIRED

Drawing board, triangular glass prism, metre scale, alpins, cellotape/ drawing pins, graph paper, protractor and white paper sheets.

PROCEDURE

1. Fix a white sheet of paper on a drawing board with the help of cellotape or drawing pins.
2. Draw a straight line XY, using a sharp pencil nearly in the middle and parallel to the length of the paper.
3. Mark points O_1, O_2, O_3, . . . on the straight line XY at suitable distances of about 8 to 10 cm and draw normals N_1O_1, N_2O_2, N_3O_3. . . . on these points (Fig. E 13.2).
4. Draw straight lines, P_1O_1, P_2O_2, P_3O_3,... corresponding to the incident rays making angles of incidence at 35°, 40°, 45°, 50°,... 60° respectively with the normals, using a protractor. Write the values of the angles $\angle P_1O_1N_1$, $\angle P_2O_2N_2$, $\angle P_3O_3N_3$,... on the white paper sheet (Fig. E 13.2).
5. Place the prism with its refracting face AB on the line XY with point O_1 in the middle of AB as shown in the figure. Draw the boundary of the prism with a sharp pencil.

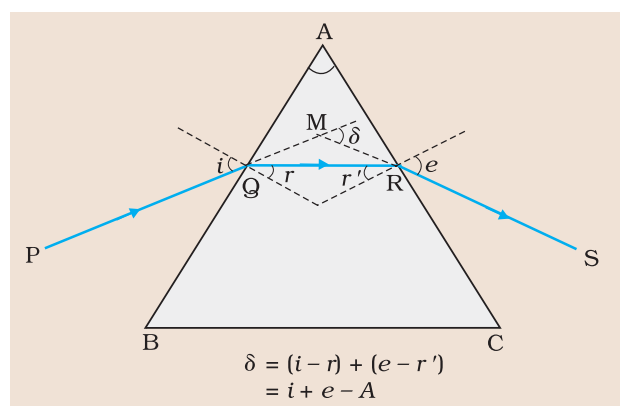

Fig. E 13.1: *Refraction of light through a glass prism for various angles of incidence*

6. Fix two alpins P_1 and Q_1 with sharp tips vertically about 10 cm apart, on the incident ray line P_1 Q_1 such that pin Q_1 is close to point O_1. Close one eye (say left) and looking through the prism, bring your right eye in line with the images of the pins P_1 and Q_1. Fix alpins R_1 and S_1 about 10 cm apart vertically on the white paper sheet with their tips in line with the tips of the images of pins P_1 and Q_1. In this way pins R_1 and S_1 will become collinear with the images of pins P_1 and Q_1.

7. Remove the pins R_1 and S_1 and encircle their pin pricks on the white paper sheet with the help of a sharp pencil. Remove the pins P_1 and Q_1 and encircle their pin pricks also.

8. Join the points (or pin pricks) R_1 and S_1 with the help of a sharp pencil and scale, to obtain the emergent ray $R_1 S_1$. Produce it backwards to meet the incident ray P_1 Q_1 (produced forward) at T_1. Draw arrowheads on P_1 Q_1 and R_1 S_1 to show the direction of the rays.

9. Measure the angle of deviation δ_1 and the angle BAC (angle A) of the prism with a protractor and write the values of these angles indicated in the diagram.

10. Repeat Steps 5 to 9 for different values of angle of incidence (40 , 45 , 50 ...) and measure the corresponding angles of deviation δ_2, δ_3... with the protractor, and indicate them in the respective diagrams (Fig E 13.2).

11. Record observations in tabular form.

OBSERVATIONS

Table E 13.1: Measuring the angle of incidence *i* and angle of deviation δ for a prism

S. No.	Angle of incidence, *i* (degrees)	Angle of deviation, δ (degrees)
1.		
2.		
3.		
--		
10.		

Plotting the graph between *i* and *δ* for the prism

Take angle of incidence *i* along *x*-axis and angle of deviation along *y*-axis, using the observed values from table. Choose suitable scales on these axes and plot a graph between *i* and δ. Take care that you draw a free hand smooth curve passing through as many points on the graph as possible. You will get a graph of the type shown in Fig. E 13.3.

8_XII_Experiment_11_13 Folder.indd 146 04-10-2018 17:13:24

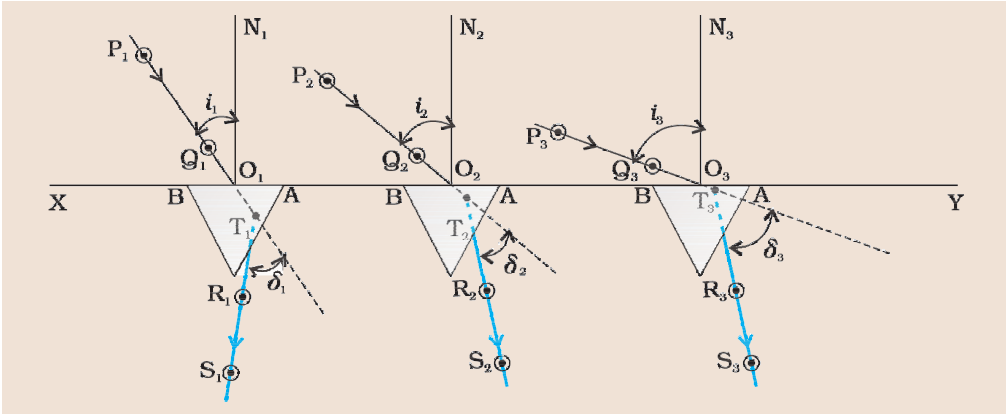

Fig. E13.2: *Refraction of light through a glass prism for various angles of incidence*

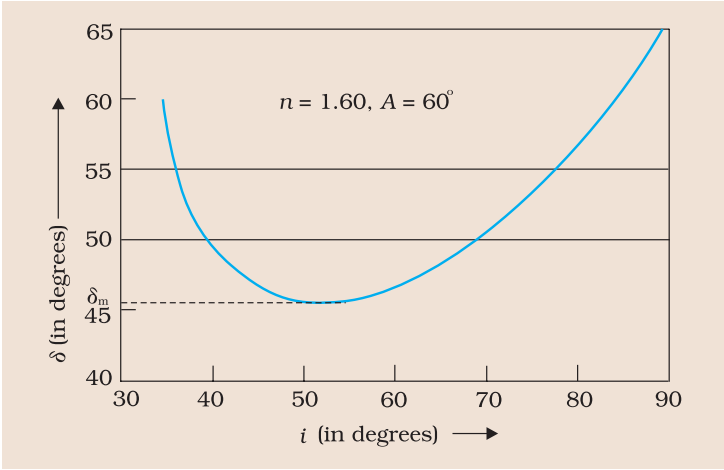

Fig. E13.3: *Graph between angle of incidence and angle of deviation*

CALCULATIONS

Draw tangent on the lowest point of the graph parallel to x-axis, read the angle of minimum deviation δ_m on the y-axis of the graph.

RESULT

Angle of minimum deviation, δ_m = ... ± ... degree

8_XII_Experiment_11_13 Folder.indd 147 04-10-2018 17:13:26

PRECAUTIONS

1. Alpins should be fixed vertically to the plane of paper.
2. Distance PQ and RS should be about 10 cm in order to locate incident and emergent rays with greater accuracy.
3. Same angle of prism should be used for all observations.
4. Position of the prism should not be disturbed for a given set of observations.

8_XII_Experiment_11_13 Folder.indd 148 04-10-2018 17:13:26

EXPERIMENT 14

AIM

To determine the refractive index of a liquid (water) using (i) concave mirror, (ii) convex lens and a plane mirror.

(i) Refractive index of water using concave mirror

APPARATUS AND MATERIAL REQUIRED

Concave mirror of small aperture and large focal length, water, a laboratory stand with rigid base and clamp arrangement (height of the stand must be more than double the focal length of the given concave mirror), a pencil, a metre scale, a spirit level, a plumb line, and some small cork pieces.

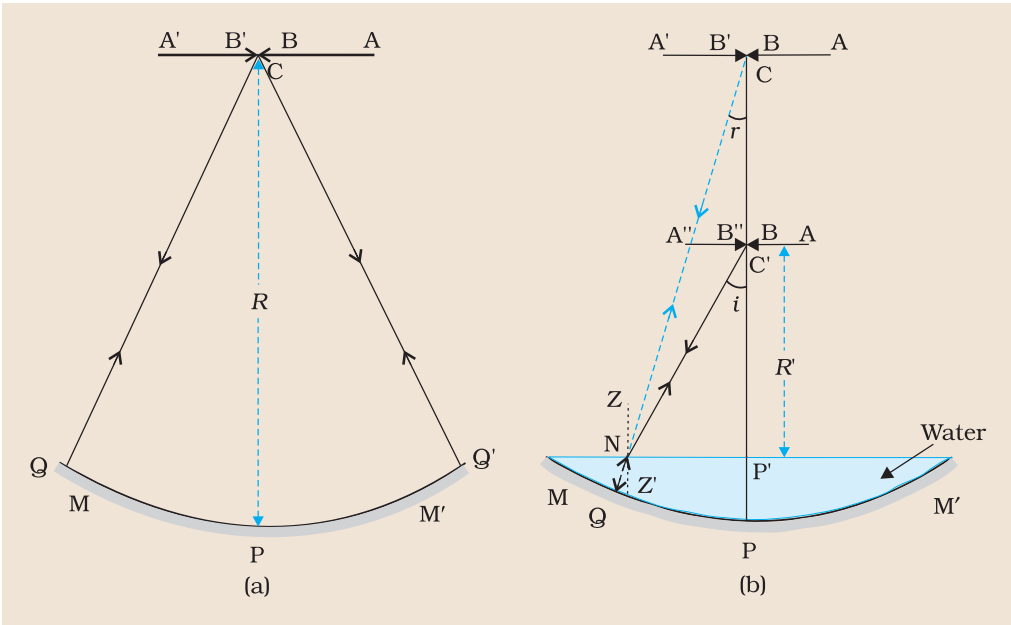

Fig. E 14.1: *Formation of image A'B' of an object AB by a concave mirror MM' placed at its centre of curvature. (a) Mirror without water and (b) Mirror with some water*

FORMULA USED

Refractive index of water with respect to air (in the experiment) is given by,

$$\eta_{wa} = \frac{\text{distance of image without water } (R = 2f)}{\text{distance of image with water } (R' = 2f')}$$

PROCEDURE

1. Obtain approximate value of focal length of the concave mirror by focusing the image of a distant object as described in Experiment-9. Twice of this focal length is an approximate value of the radius of curvature of the mirror.

Note: Do not look at the sun's image in a concave mirror as it may hurt your eyes.

2. Place the given concave mirror on the base of a firm and stable laboratory stand keeping its reflecting surface upwards. Use a spirit level to ensure that the plane on which the mirror rests is horizontal. It makes the principal axis of the mirror vertical. Some pieces of paper, plasticine or cork may be used to keep the position of mirror stable on the stand.

3. Fix a sharp pencil in the clamp and place it horizontally just above the mirror. Adjust the position of the pencil such that its tip B lies just above the pole P of the mirror or lies on the principal axis of the mirror.

4. Shift the clamped pin to a distance roughly equal to twice the rough focal length of the concave mirror (obtained in Step 1) from the pole P of the mirror placed on the base of laboratory stand. Once again verify that the tip of the pencil and pole P lie along the same vertical line (principal axis of the mirror).

5. Adjust the position of the pencil till the parallax between the tip of the pin and its inverted image is removed.

6. Measure the vertical distance between the tip of the pencil and the mirror using a plumb line and metre scale. This distance would be the real radius of curvature of the mirror.

7. Pour some water on the curved surface of the mirror.

8. Lower the pencil slowly, till once again the parallax between the tip of the pencil and its inverted image formed by the water-filled mirror is removed.

9_XII_Experiments_14_17 Folder.indd 150 05-10-2018 12:53:50

9. Remove water from the mirror and measure the vertical distance between the tip of the pencil and the mirror. This distance would be the apparent radius of curvature of the water-filled mirror.

10. Repeat the experiment (Steps 2 to 9) at least two more times.

OBSERVATIONS

1. Approximate value of the focal length of the concave mirror, f = ...cm

2. Approximate value of the radius of curvature, R = 2f = ...cm

Table E 14.1 Observation for R, R' and n_{wa}

S. No.	Position of pencil with respect to pole P		n_{wa} = R/R'	Δn_{wa}
	For concave mirror without water, distance PC R (cm)	For water – filled mirror, distance PC' R' (cm)		
1.				
2.				
3.				
	Mean			

Note: Since a very small quantity of water is taken in the mirror, therefore PC' ~ P'C'

CALCULATIONS

Calculate n_{wa} and its mean value.

Error

$$\frac{\Delta n_{wa}}{n_{wa}} = \frac{\Delta R}{R} + \frac{\Delta R'}{R'}$$

$$\therefore \Delta n_{wa} = \left[\frac{\Delta R}{R} + \frac{\Delta R'}{R'}\right] n_{wa}$$

RESULT

The refractive index of water with respect to air is n_{wa} = ... where n_{wa} is mean value of glass with respect to the medium air.

9_XII_Experiments_14_17 Folder.indd 151 05-10-2018 12:53:50

PRECAUTIONS

1. Pencil should be kept horizontal and above the curved reflecting surface of the horizontally placed concave mirror such that the tip of the pencil lies above the pole of the mirror on its vertical principal axis.
2. Aperture of mirror should be small.
3. The mirror should be very thin otherwise multiple reflections will form an unclear image.
4. The quantity of water taken in the mirror should be sufficient so that the water surface remains horizontal, or else the surface may not remain horizontal because of surface tension.
5. Eye should be kept at a distance of more than 25 cm from the pencil.

(ii) Refractive index of water using convex lens and a plane mirror

APPARATUS AND MATERIAL REQUIRED

Double convex lens (focal length nearly 20 cm), plane mirror (bigger in size than the aperture of the lens), spherometer, laboratory stand fixed with a pencil in a clamp, metre scale, plumb line and water dropper.

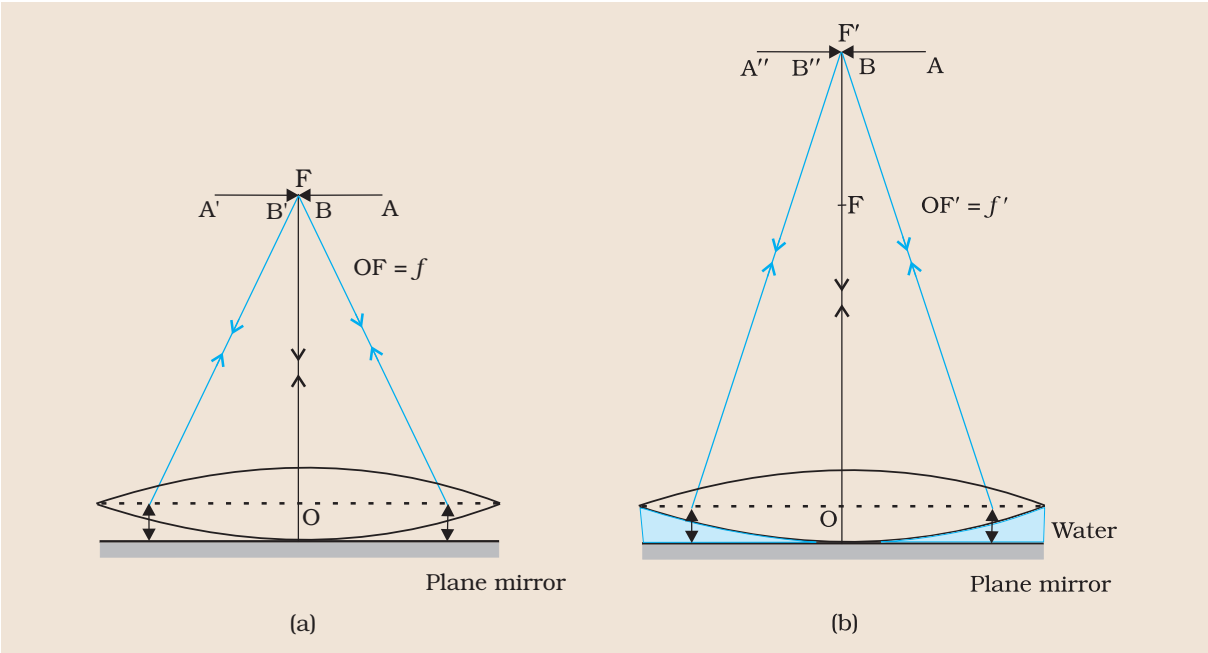

Fig. E 14.2: *Image formed by a equiconvex lens backed by a plane mirror coinciding with the object AB. (a) A' B' when there is air in between the lens and the mirror; and (b) A'' B'' when there is water in between the lens and mirror.*

9_XII_Experiments_14_17 Folder.indd 152 05-10-2018 12:53:50

FORMULA USED

1. The focal length of the combination of two lenses (f') is related to focal length of glass lens (f)and focal length of water lens (f_w) as,

$$\frac{1}{f'} = \frac{1}{f} + \frac{1}{f_W}$$

$$\text{or } f_W = \frac{ff'}{f - f'}$$

Also, from lens maker's formula for a plano-concave lens (water lens formed below the glass convex lens in this experiment)

$$\frac{1}{f_w} = (n_{wa} - 1)\frac{1}{R}$$

$$\text{or } n_{wa} = 1 + \frac{R}{f_w}$$

Where R is the radius of curvature of the lens and n_{wa} is the refractive index of water with respect to air.

PROCEDURE

1. Place the plane mirror on the base of a rigid laboratory stand keeping its reflecting surface upwards.
2. Place the convex lens on the plane mirror.
3. Fix a sharp-edged bright pencil in the clamp and place it horizontally and above the lens. Adjust the position of the pencil such that its tip B lies vertically above the optical centre of the convex lens. A plumb line and a spirit level may be used to achieve this.
4. Shift the clamped pencil gradually upward looking at the image and bring it to a height such that the tip B of the pencil exactly coincides with the tip of its image B'. Ensure that there is no parallax between the object pencil and its image. Measure the distance OF (Fig. E14.2a). For this, measure the distances of the pencil from the upper and lower surfaces of the lens and take OF = f as the average of these two distances.
5. With the help of a dropper, put a few drops of water under the lens so that the space between mirror and lens is filled with water.
6. Move the object pencil upward and remove the parallax between the tip of the object pencil and its image formed by the lens mirror

9_XII_Experiments_14_17 Folder.indd 153 05-10-2018 12:53:50

system. Measure the distance OF' [Fig. E 14.2b]. Here again, as before, measure the distances of the pin from the two surfaces of the lens and take OF' = f' as their average.

7. Repeat the experiment and record your observations in the table.

OBSERVATIONS

1. Mean value of distance between the two legs of the spherometer l = ...cm
2. Mean value of sagitta (bulge of the lens) h = ...cm
3. Radius of curvature of the lens can be calculated using the following formula : $R = \left(\frac{h}{2} + \frac{l^2}{6h}\right)$

Mean value of the radius of curvature of the lens R = ...cm

Table E 14.2 Focal length of convex lens and water plano-convex lens

S. No.	Position of the pencil with respect to optical centre O						$f_w = \frac{f f'}{f - f'}$	n_{wa}
	Without water (OF =f)			With water (OF' =f')				
	Distance of the pencil from			Distance of the pencil from				
	Upper surface of the lens	Plane mirror	$\frac{d_1 + d_2}{2}$	Upper surface of the lens	Plane mirror	$\frac{d_3 + d_4}{2}$		
	d_1 (cm)	d_2 (cm)	f (cm)	d_3 (cm)	d_4 (cm)	f ' (cm)		
1.								
2.								
3.								
							Mean	

RESULT

The refractive index of a given liquid (say water) with respect to air is n_{wa}=.... Here, n_{wa} is the mean value.

9_XII_Experiments_14_17 Folder.indd 154 05-10-2018 12:53:51

PRECAUTIONS

1. Pencil should be kept horizontal and its tip should be above the optical centre of the lens on its vertical principal axis otherwise it will be difficult to remove the parallax.
2. The thin lens should be used so that the distance measured from its surface is nearly equal to the distance measured from the optical centre. Still it is better to measure distance from both the surface and take the average for f or f'.
3. Water should be gently put between the mirror and the lens surface with the help of a dropper so that it may fill up the air space between them without disturbing the position of the lens.

9_XII_Experiments_14_17 Folder.indd 155 05-10-2018 12:53:51

EXPERIMENT 15

AIM

To draw the I-V characteristic curves of a p-n junction in forward bias and reverse bias.

MATERIAL REQUIRED

A p-n junction diode 1N4007; a resistor 240 Ω, one variable voltage power supply (0-15V), two multimeters, connecting wires, a breadboard and connecting leads.

PROCEDURE

1. Keep the supply off to begin with breadboard (a ready made arrangement for making connections) Fig. E15.1.

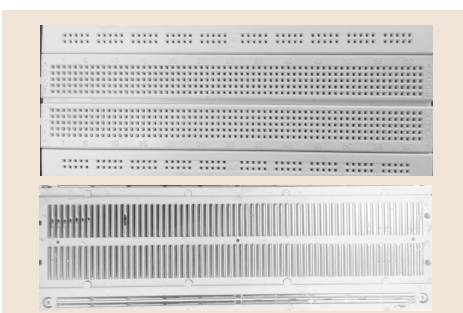

Fig. E 15.1: *Breadboard and connections underneath*

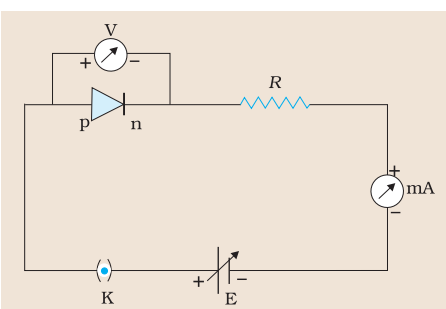

Fig. E 15.2: *Forward biasing for a p-n junction diode*

2. Using breadboard join the various components as shown in circuit diagram (Fig E 15.2).
3. Using knob of multimeter select the range of multimeter to 200 mA DC range. Switch on the supply keeping voltage minimum and note down the least count of milliammeter at this range.
4. Similarly select the range of second multimeter to 2V DC range and note down the least count of the voltmeter.
5. Give a small voltage (say 0.5V) to the circuit by gently turning the knob of the power supply. Note the readings in voltmeter and milliammeter. Increase voltage across the junction from O to 1V in steps of 0.1V and record the corresponding milliammeter reading.
6. Continue increasing the supply voltage and recording the voltmeter and ammeter readings for previously selected complete range of the milliammeter.
7. Take out the p-n junction diode and re-connect it by reversing its terminals (Fig. E 15.3). Select 2000μA range in the multimeter to make it microamperemeter, and select 20V range for voltmeter.

8. Turning supply voltage knob, change voltage across the junction in steps of 0.2 V to begin with and read the corresponding values of microammeter each time. After 1V, increase voltage in steps of 1V and again read the corresponding values of microamperemeter each time.

9. Make an observation table for forward and reverse bias as shown in Tables E 15.1 and 15.2.

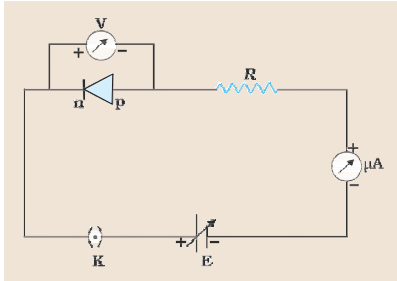

Fig. E 15.3: *Reverse biasing for a p-n junction diode*

10. Draw a graph between V and I, taking V on *x*-axis and I on *y*-axis for these two cases. The graph for forward bias being in first quadrant and for reverse bias in third quadrant.

OBSERVATIONS

Table E 15.1: Variation of forward current with voltage across the diode (forward bias)

S. No.	Forward Voltage V_f (V)	Forward Current I_f (μA)
1.		
2.		
3.		

Table E 15.2: Variation of Reverse current with voltage across the diode (Reverse bias)

S. No.	Reverse Voltage V_r (V)	Reverse Current I_r (μA)
1.		
2.		
3.		

RESULT

1. Typical I-V characteristics of p-n junction diode 1N4007 have been successfully plotted

2. The knee voltage for the given diode is -----V.

9_XII_Experiments_14_17 Folder.indd 157 05-10-2018 12:53:53

PRECAUTIONS

1. In your kit, you have two power supplies, you can use any one of them.
2. The value of the series resistance connected in the circuit should not be less than 240 Ω (to limit maximum forward current).
3. The power supply should not remain on for a long time unnecessarily.
4. The maximum current through the diode in forward bias must be limited below it maximum rating. (The 1N4007 diode has a maximum forward current rating of 1A).
5. The applied reverse bias voltage should not exceed the reverse break down voltage of the p-n junction diode (The 1N4007 diode has a peak reverse break down voltage of 1000 V).

DISCUSSION

The complete reverse bias characteristics cannot be plotted up to the breakdown voltage due to the high reverse break down voltage rating of the p-n junction diode (IN 4007 Reverse break down voltage = 1000V).

The diode, anode and cathode can be identified by looking for a marking at one end of the diode. The ring marking is for the cathode (n) side of the p-n junction.

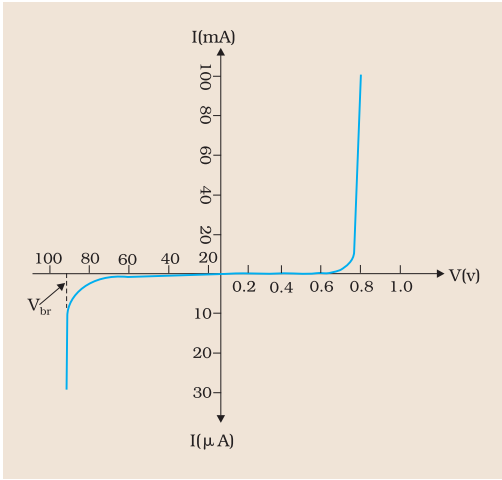

Fig. E 15.4: *Typical I-V characteristics of a silicon diode in forward biasing and reverse biasing*

9_XII_Experiments_14_17 Folder.indd 158 05-10-2018 12:53:53

EXPERIMENT 16

AIM

To draw the characteristic curve of a Zener diode and to determine its reverse breakdown voltage.

MATERIAL REQUIRED

A 10V Zener diode, a resistor 820 Ω, $\frac{1}{2}$ W; one variable voltage (0-15v) power supply, two digital multimeter, connecting wires, a breadboard and connecting lead.

PROCEDURE

1. Ensure the power supply is switched off. Connect the circuit on the breadboard according to the circuit diagram (Fig E 16.2). Select the 200 mA range for multimeter M_1 and 2V range for multimeter M_2 and study forward bias characteristics of the pn junction diode in Experiment 15.

2. Reverse the connections of the Zener diode to connect it in reverse bias mode. Select the 200 μA range for multimeter M_1 and 20V range for multimeter M_2. Switch ON the power supply and keep it at its minimum output value (voltage adjustment knob fully counter clock wise). Increase the voltage in steps of 1V (readings on M_2) and note the current. If the multimeter M_2 shows a display of 1(at the left end of the display), switch the current range to the next higher range (you have exceeded the current measurement range). Measure the observations till the full ouput range of the power supply.

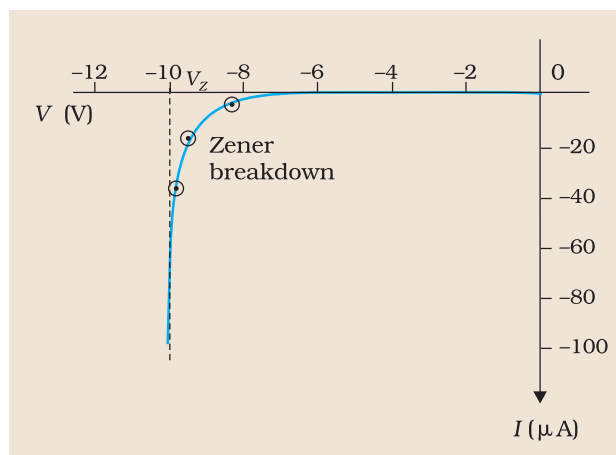

Fig. E 16.1: *Zener diode characteristics curve*

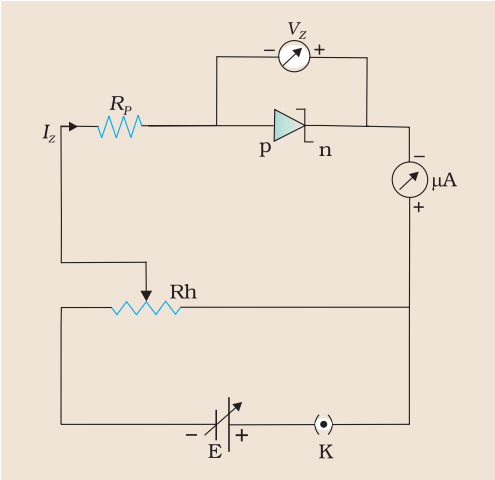

Fig. E 16.2: *Circuit for Zener diode characteristic curve*

3. Record the observations in tabular form as provided and plot a graph between voltage (x-axis) and current (y-axis). The curve is plotted in the third quadrant.

RESULT

1. The characteristics curve for the Zener diode was successfully plotted.
2. The Zener break down voltage of the Zener diode is —V

Table E 16.1:

S.No.	For Zener diode	
	Voltmeter reading Vr (V)	Microammeter /Milliammeter Reading Ir(A) (mA) Ir (μA)
1		
2		
3		

PRECAUTIONS

1. In your kit you have two power supplies, you can use any one of them.
2. The value of the series resistance connected in the circuit should not be less than 820 Ω (to limit maximum forward current).
3. The power supply should not remain on for a long time unnecessarily.
4. The maximum current in reverse breakdown should be limited to prevent Zener damage.

DISCUSSION

The diode, anode and cathode can be identified by a tiny marking at one end of the diode. The tiny marking indicates the cathode in diode of the Zener diode.

9_XII_Experiments_14_17 Folder.indd 160 05-10-2018 12:53:53

EXPERIMENT 17

AIM

To study the characteristics of a common emitter npn(or pnp) transistor and to find out the values of current and voltage gains.

FORMULAE USED

(i) Input resistance, r_i is defined as the ratio of change in base-emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at constant collector-emitter rottage (V_{CE}), i.e.,

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE} = \text{constant}}$$

(ii) Output resistance, r_o is defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at constant current I_B, i.e.,

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_c}\right)_{I_B = \text{constant}}$$

(iii) Current Gain, β is defined as the ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) when the collector to emitter voltage V_{CE} is fixed, i.e.,

$$\beta = \left(\frac{\Delta Vc}{\Delta I_B}\right)_{V_{CE} = \text{constant}}$$

(iv) Voltage Gain, A_v is defined as the change in output voltage (ΔV_o) at the collector for a small voltage change ΔV_i in the emitter-base, i.e.,

$$A_v = \frac{\Delta V_o}{\Delta V_i} = \frac{\Delta I_c r_o}{\Delta I_i r_i}; \; A_v = \beta \frac{r_o}{r_i}$$

MATERIAL REQUIRED

PNP Transistor BC 548 or NPN Transistor BC 547, two variable power supply (0-15V, 500 mA), three digital multimeters, 220Ω resistors, connecting wires and one breadboard.

PROCEDURE

The power supply provided in the kit has two separk variable outputs. One can be used for base-emitter junction and other can be used for collector-base junction. With the help of multimeter ensure that V_{BE} is varied in the range 0–3 V only.

Output characteristics

1. Keep the power supply off.
2. Using breadboard make connections as shown in circuit in Fig E 17.2.
3. Set ranges of multimeters accordingly.
4. Set I_B to 10 μA by turning the knob of power supply P_1. Now using P_2 increase the value of V_{CE} in steps of 0.1V and note the corresponding values of I_C. Repeat for values of V_{CE} and I_C till the complete range of supply voltage V_{CC} (P_2 in fully clockwise).

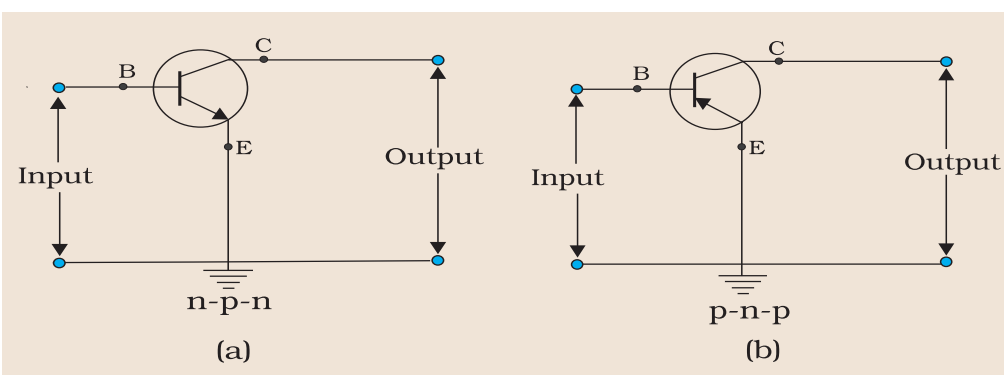

Fig. E 17.1: *Common emitter configuration*

9_XII_Experiments_14_17 Folder.indd 162 05-10-2018 12:53:54

5. Change of value to I_B to 20 A and repeat the experiment.
6. Similiarly, repeat the experiment at I_B = 30 A and 40 A.
7. Tabulate the observations and draw graphs for V_{CE} vs I_C at constant I_B, thus obtaining four distinct curves.

Input characteristics

8. Setup the circuit as per circuit diagram Fig E 17.2.
9. Set V_{CE} at 5V, increase V_{BE} in steps of 0.1V and record corresponding values of I_B till maximum value of supply V_{BB} (fully clockwise P_1).
10. Repeat the experiment for V_{CC}=10V and 15V, draw graphs for at constant V_{CE}, thus obtaining 3 distinct curves.

Transfer characteristics

11. Keeping V_{CC} constant, vary the value of I_B in steps of μA and record the corresponding values of I_C.
12. Plot a graph between I_C and I_B taking I_B on *x*-axis and I_C on y-axis.

Note: For n-p-n transistor, reverse the polarities of input and output varible supply and connect and set the multimeter accordingly.

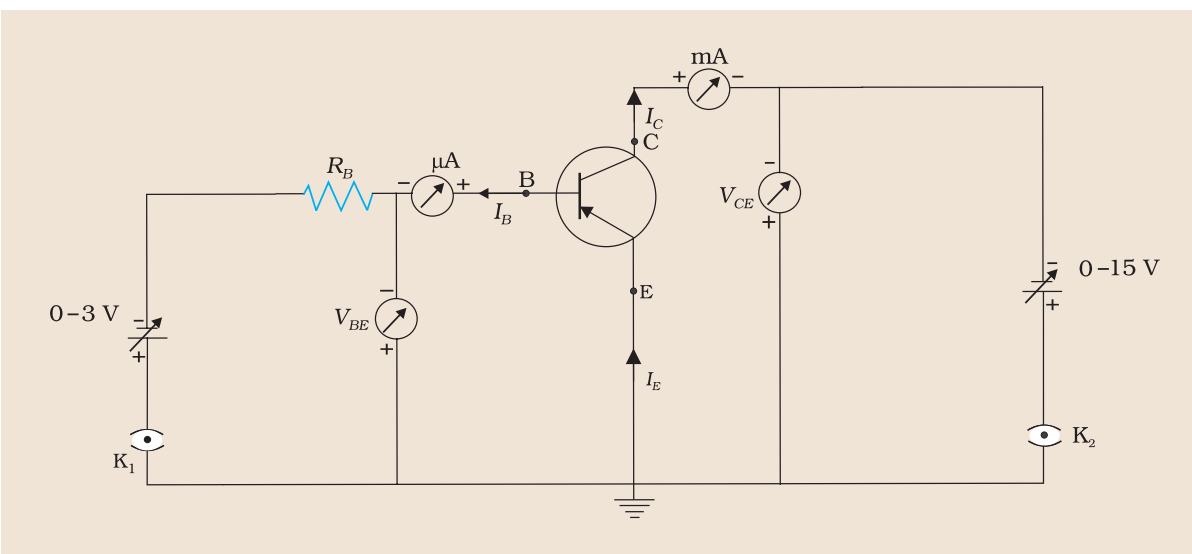

Fig. E 17.2: *Circuit diagram for studying the characteristics of a p-n-p transistor, in CE configuration*

9_XII_Experiments_14_17 Folder.indd 163 05-10-2018 12:53:54

RESULT

1. The graphs 17.3 *a,b,c* show the input, output and transfer characteristics respectively of transistor BC 547.
2. The current gain of the transistor, β .....
3. The voltage gain of the transistor, A_V .....
4. At V_{CE} = ... V, Input resistance r_i = ... Ω
5. At V_{BE} = ... V, Output resistance r_0 = ... Ω

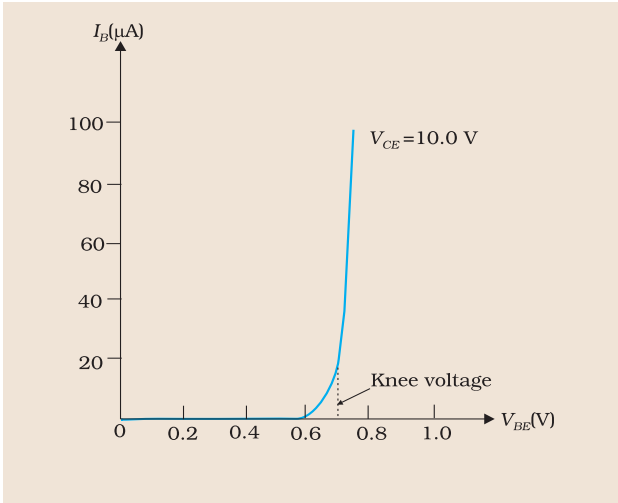

Fig. E 17.3 (a): *Typical input characteristic of a transistor in CE configuration*

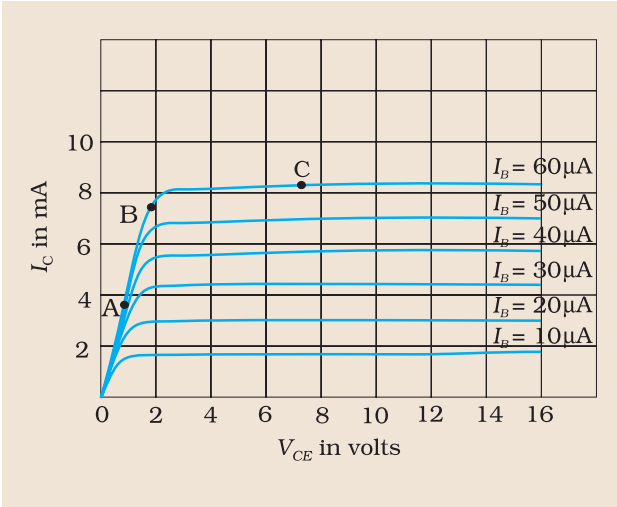

Fig. E 17.3 (b): *Typical output characteristics of a transistor in CE configuration*

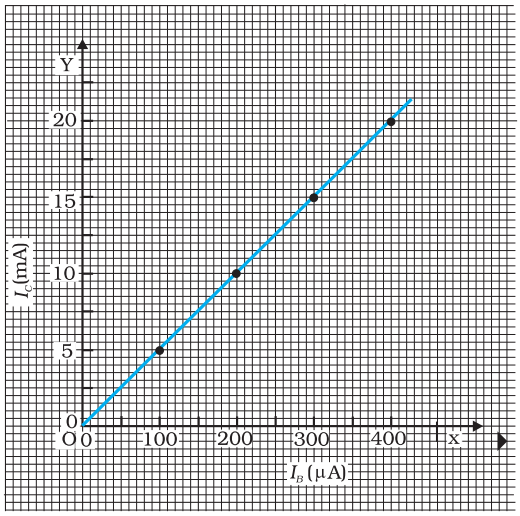

Fig. E 17.3 (c): *Typical transfer characteristic of a transistor in CE configuration*

PRECAUTIONS

1. The base current I_B must be kept below 1.5 mA or 1500 μA to prevent damage to the base-emitter junctions.

9_XII_Experiments_14_17 Folder.indd 164 05-10-2018 12:53:54

ACTIVITY 1

AIM

To assemble the components of a given electrical circuit.

APPARATUS AND MATERIAL REQUIRED

Resistor, two multimeters (used as voltmeter and ammeter), 2V battery, one-way key, rheostat, sand paper and connecting wires.

PROCEDURE

1. Connect the components as shown in Fig. A 1.1.
2. After closing the key K, check that the multimeter used as voltmeter and multimeter used as an ammeter displays positive readings.
3. If the reading is not positive in ammeter/voltmeter; reverse the connections at their terminals.
4. If display shows 1, check the continuity of the assembled circuit using another multimeter (see Activity 4).

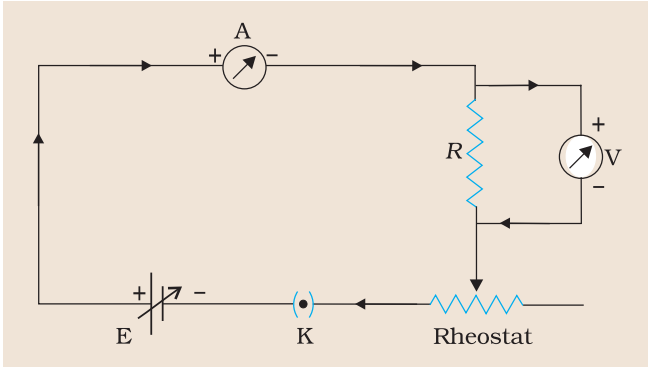

Fig. A 1.1: *Assembling of given components*

RESULT

The components of the electrical circuit were assembled.

PRECAUTIONS

1. The positive terminal of the battery should be connected to the positive terminal of ammeter (multimeter used) and positive terminal of the voltmeter (multimeter used).
2. The multimeter used as an ammeter should be connected in series with the resistor and the multimeter used as a voltmeter should be connected in parallel with the resistor.
3. Sand paper should be used to clean the ends of connecting wires and leads of the components terminals. Grease/oil or the oxide layer on the surfaces of the connecting wires is insulating in nature and needs to be removed. However, do not clean the plugs and keys with sand paper. Excessive use of sand paper in such a case will make the plug unfit to be used with the key.

10_XII_Activity_1_6 Folder.indd 166 05-10-2018 12:58:27

ACTIVITY 2

AIM

To draw the diagram of given open circuit comprising atleast a cell/ battery, resistor/rheostat, key, ammeter and voltmeter. Mark the components that are not connected in proper order. Correct the circuit and also draw the corrected circuit diagram.

MATERIAL REQUIRED

A given open circuit comprising at least a cell or a battery, plug key, resistor, rheostat, multimeter used as an ammeter, multimeter used as a voltmeter, connecting wires and sand paper.

Teacher's preparation before assigning the activity.

Teacher may prepare 3–4 circuits comprising open circuit/ components connected not in proper order/components connected with wrong polarity/loose connections, etc.

For this purpose, teacher may use circuits that are to be part of prescribed experiments.

PROCEDURE

1. Identify the incorrectness(es) of the given circuits.
2. Draw the diagrams in your notebook of the circuits given by your teacher.
3. Consider given circuits one by one and mark in Table 2.1, the various components which have not been connected in proper order.
4. Draw the correct circuit diagram in each case.
5. Connect the electrical components according to corrected circuit diagram.
6. Close the key in the circuit to verify if the corrected circuit is functional.

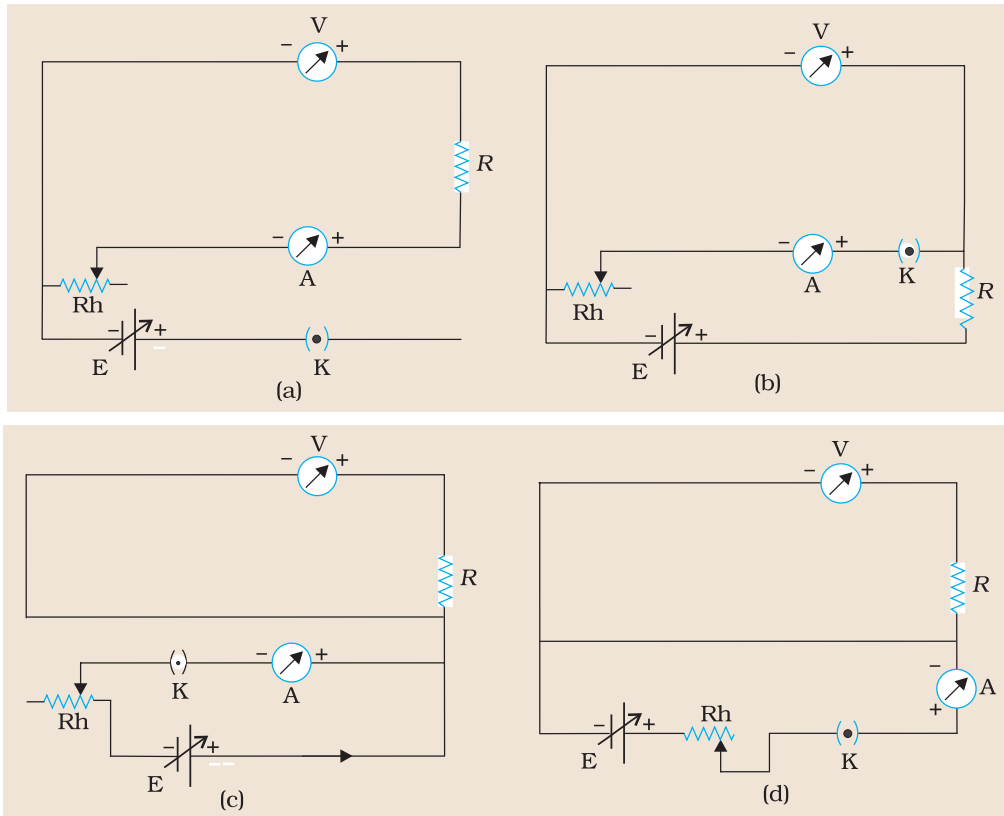

Fig. A 2.1 (a),(b),(c),(d): *Given circuits*

OBSERVATION

Table A 2.1: Mark a (✓) in the appropriate column

S. No	Circuit Component	correct Connection	Incorrect Connection
1.	Battery/cell		
2.	Resistor		
3.	Rheostat		
4.	Key		
5.	Ammeter		
6.	Voltmeter		

RESULT

The electrical circuit assembled as per the corrected circuit diagram is functional.

10_XII_Activity_1_6 Folder.indd 168 05-10-2018 12:58:27

ACTIVITY 3

AIM

To measure the resistance and impedance of an inductor with or without iron core.

APPARATUS AND MATERIAL REQUIRED

Inductor coil with iron core, battery eliminator with ac and dc output, digital multimeter, one-way key and connecting wires.

PRINCIPLE

An inductor is a cylindrical coil of large number of turns of copper wire usually wound on a hollow cylinder. The opposition to the flow of dc current offered by such a coil or its resistance is given as

$$R = \frac{V}{I} \qquad \text{(A 3.1)}$$

Where V is the potential difference across the coil and I is the dc current through that coil. On introducing the core of soft iron, the new values of potential difference across the coil, V′and the current, I′ through it are measured again. The resistance of the coil with iron core becomes,

$$R' = \frac{V'}{I'} \qquad \text{(A 3.2)}$$

The opposition offered by the coil to the flow of alternating current is known as impedance Z. If V_{ac} and I_{ac} respectively be the alternating voltage and alternating current through the coil, without Iron core, then the impedance of the coil, is given as

$$Z = \frac{V_{ac}}{I_{ac}} \qquad \text{(A 3.3)}$$

On introducing the iron core inside the coil, the value of impedance Z' becomes

$$Z' = \frac{V'_{ac}}{I'_{ac}} \qquad \text{(A 3.4)}$$

Where, V'_{ac} is the alternating voltage across the inductor with core inside and I'_{ac} is the alternating current through the inductor with the core inside.

PROCEDURE

1. **For resistance of inductor without iron core**, arrange the apparatus as per the circuit diagram Fig. A 3.1 (a) by keeping the key K open.

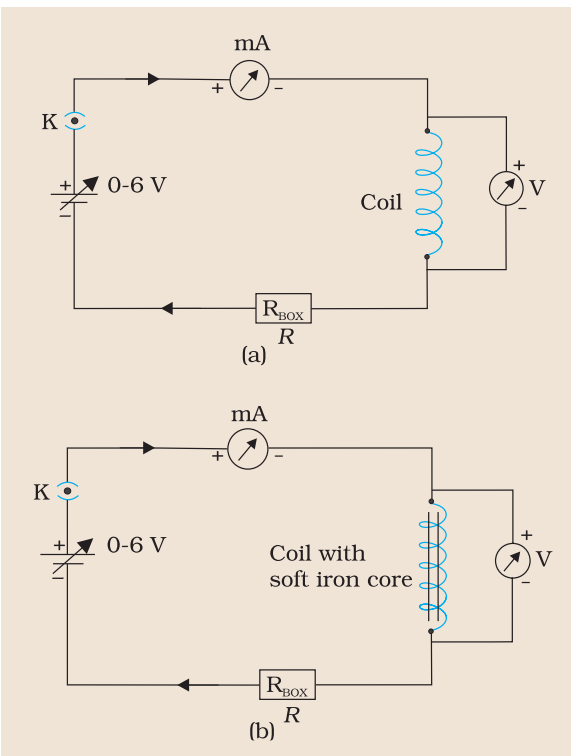

Fig. A 3.1: *Inductor in a* dc *circuit: measurement of resistance with (a) an air core (b) a soft iron core*

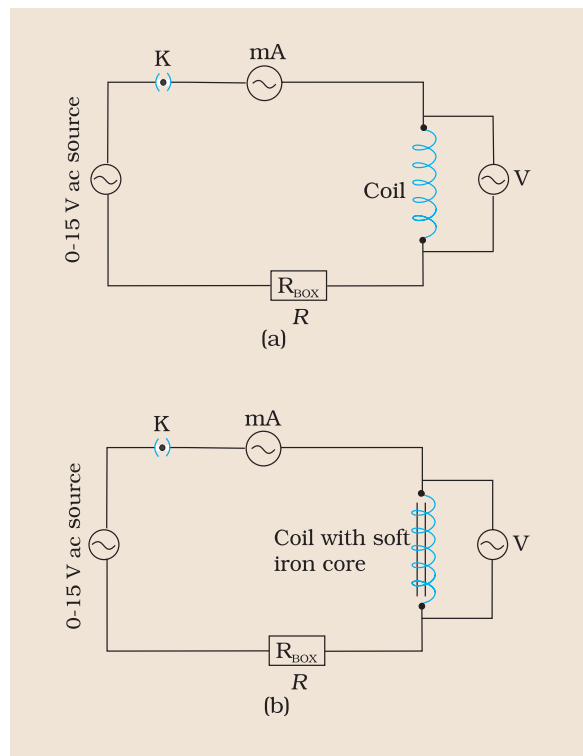

Fig. A 3.2: *Inductor in an* ac *circuit: measurement of impedance with (a) air core (b) soft iron core*

10_XII_Activity_1_6 Folder.indd 170 05-10-2018 12:58:28

2. Connect the dc source and one multimeter in series with inductor and another multimeter in parallel with it.
3. Select dc voltage range in multimeter connected in parallel and dc current range in multimeter connected in series.
4. Adjust the battery eliminator to the lowest setting and switch ON the eliminator. Plug in the key. Measure the dc current and dc voltage across the inductor.
5. Set the eliminator to higher voltages in succession and record the dc current and dc voltage across the inductor.
6. **For resistance of inductor with soft iron core,** introduce the iron core such that it is fully inside the coil [Fig A 3.1(b)].
7. Repeat Steps 4 and 5 and record the current and voltage across the inductor.
8. **For measurement of impedance of inductor without iron core,** use ac output of eliminator with various settings (2V, 4V, 6V), two multimeters and connect them as shown in Fig. A3.2(a).
9. Select ac range in multimeters for measuring ac voltage and ac current.
10. Repeat Steps 4 and 5 for alternating current and alternating voltage. Record the current and voltage across the inductor.
11. **For measurement of impedance of inductor with soft iron core,** introduce the core of the soft iron inside the coil such that the core is fully inside the coil [Fig. A 3.2(b)].
12. Repeat Steps 4 and 5 for alternating current and alternating voltage. Record the current and voltage across the inductor.

OBSERVATIONS

1. Range of dc voltmeter = 0 to ... V
2. Least count of dc voltmeter = ...V
3. Range of dc ammeter = 0 to ... mA
4. Least count of dc ammeter = ... mA
5. Range of ac voltmeter = 0 to ... V
6. Least count of ac voltmeter = ... V

10_XII_Activity_1_6 Folder.indd 171 05-10-2018 12:58:28

7. Range of ac ammeter = 0 to ... mA
8. Least count of ac ammeter = ...mA

Table A 3.1: Resistance of the inductor without and with iron core

S. No.	Applied dc voltage	Without iron core			With iron core		
		Voltage V (V)	Current I (mA)	$Z = \frac{V}{I}$ Z (Ω)	Voltage V' (V)	Current I' (mA)	$Z' = \frac{V'}{I'}$ Z' (Ω)
1.							
2.							
3.							
4.							
			Mean			Mean	

Table A 3.2: Impedance of the coil without and with iron core

S. No.	Applied ac voltage	Without iron core			With iron core		
		Voltage V (V)	Current I (mA)	$R = \frac{V}{I}$ R (Ω)	Voltage V' (V)	Current I' (mA)	$R' = \frac{V'}{I'}$ R' (Ω)
1.							
2.							
3.							
4.							
			Mean			Mean	

CALCULATIONS

1. Calculate the ratio of voltage and current for each observation to get resistance and impedance.
2. Calculate the mean values of the resistance and impedance in each case, i.e., without and with iron core.

10_XII_Activity_1_6 Folder.indd 172 05-10-2018 12:58:29

RESULT

1. The dc resistance of the inductor coil without iron core =...Ω
2. The dc resistance of the inductor coil with iron core =...Ω
3. The impedance of the inductor coil without iron core =...Ω
4. The impedance of the inductor coil with iron core =...Ω

PRECAUTIONS

1. The iron core should be inserted completely within the coil.
2. The ends of the connecting wires should be cleaned with sand paper before making the connections.

10_XII_Activity_1_6 Folder.indd 173 05-10-2018 12:58:29

ACTIVITY 4

AIM

To measure the resistance, voltage (dc/ac), current (dc) and check continuity of a given circuit using a multimeter.

PROCEDURE

1. To measure resistance

i. Take a digital multimeter (Fig. A 4.1) and switch it on. Connect black lead of the multimeter to COM terminal of the multimeter and red lead of the multimeter to V Ω mA terminal.

ii. Take a resistance box. Set 200 Ω in this resistance box.

iii. Set the multimeter knob to 2 kΩ.

iv. Connect the two leads of the multimeter to the two terminals of the resistance box. Note the reading on multimeter and compare it with value set on resistance box.

v. Repeat the activity by setting different values of resistance on resistance box.

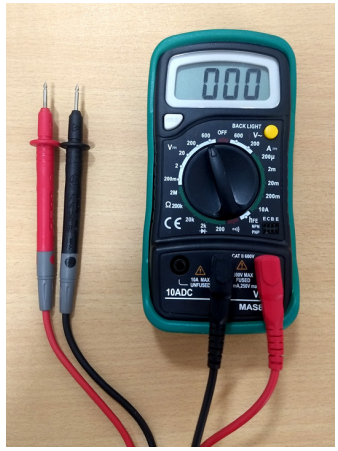

Fig. A 4.1: *Digital multimeter*

Note: If multimeter shows '1' while measuring the resistance, increase the range by shifting resistance knob to higher values of resistance.

2. To measure dc/ac voltage

i. Take a digital multimeter and switch it on. Connect black lead of the multimeter to COM terminal of the multimeter and red lead of the multimeter to V Ω mA terminal.

ii. For measuring dc voltage take a dc source and set to some value say 5V.

iii. Set multimeter knob to 20 V (dc). Connect the two leads of the multimeter to the two terminals of the dc source appropriately.

Note the reading on the multimeter and compare it with the value set on the dc source. Repeat activity by changing the value dc voltage source.

iv. For measuring ac voltage, replace dc source with ac source. Set multimeter knob to ac voltage range.

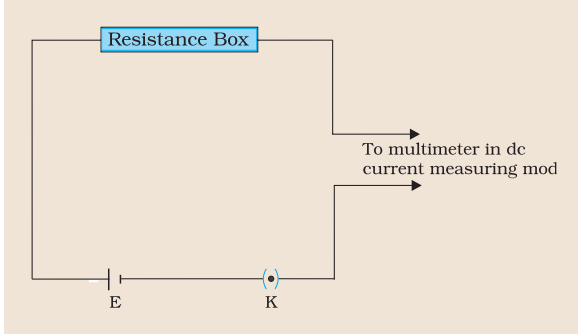

Fig. A 4.2: *Use of multimeter as a* dc *ammeter*

Note: In this case also, if multimeter show '1' while measuring the voltage, increase the range by shifting the knob to higher range of voltages.

3. To check continuity

i. Take a digital multimeter and switch it on. Connect black lead of the multimeter to COM terminal of the multimeter and red lead of the multimeter to V Ω mA terminal.

ii. Set the multimeter knob to diode symbol (→|) or 200 Ω resistance or sound symbol.

iii. Take any wire. Connect both the ends of the wire to multimeter leads.

iv. If wire is continuous than multimeter will show 0 Ω or it will give you sound. If there is any breakage in the wire then the multimeter reading will show '1' and there will be no sound.

4. To measure 'dc' current

i. Take a digital multimeter and switch it on. Connect black lead of the multimeter to COM terminal of the multimeter and red lead of the multimeter to 10A DC terminal of the multimeter.

ii. Connect the circuit as shown in the Fig. A 4.2.

iii. Set the multimeter knob to dc current range.

iv. Close the circuit by inserting key. Note the reading in the multimeter.

v. Calculate the current theoretically and compare it with multimeter value.

vi. Repeat the experiment by changing dc voltage.

10_XII_Activity_1_6 Folder.indd 175 05-10-2018 12:58:29

ACTIVITY 5

AIM

To assemble a household circuit comprising three bulbs, a socket, three (On/Off) switches, a fuse and a power source (3V ac source).

APPARATUS

Three torch bulbs of 2.5V each with holders, three 1-way keys (or switched), connecting wires with crocodile clips and ac source of 3 V.

Note: This is a model circuit to understand how different appliances are connected. In actual household circuit, the source is A.C. mains (220 V). Wire 1 is called the live wire and Wire 2 the neutral wire. The dotted line 3 shown is the earth wire (it has been given as it is used in the actual household circuit). The fuse is always connected to the live wire (for the model circuit it does not matter which wire 1 or 2 the fuse is connected to).

PROCEDURE

1. Take the bulbs B_1, B_2, B_3 and connect them in series with switches S_1, S_2 and S_3 respectively. Connect B_1, B_2, B_3 alongwith S_1, S_2 and S_3 in parallel with each other as shown in Fig. A 5.1.
2. Connect fuse F in series as shown in the Fig. A 5.1.
3. Press the switches S_1, S_2 and S_3 one by one and observe the bulb that is switched on and off independently of the other bulb.
4. Press all the switches simultaneously and observe what happens. Record your observations.

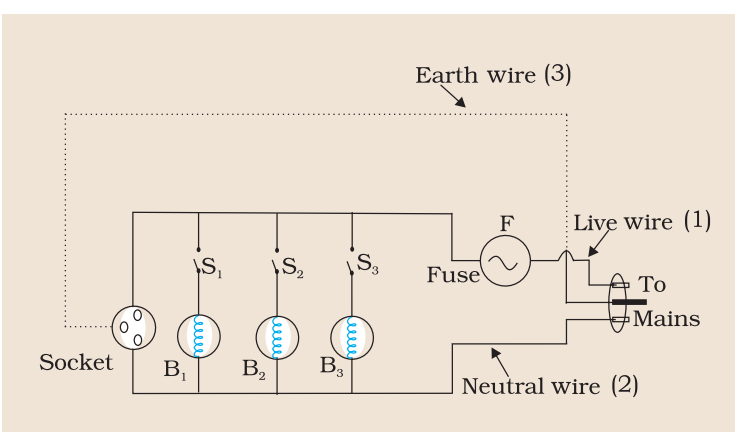

Fig. A 5.1:

ACTIVITY 6

AIM

To study the variation in potential drop with length (potential gradient) of a wire for a steady current.

APPARATUS AND MATERIAL REQUIRED

Potentiometer, 2V battery, multimeter, plug key, jockey, rheostat, connecting wires etc.

PRINCIPLE

If a steady current is flowing through a wire of uniform area of cross section and having its resistance per unit length constant, potential drop V across two points of the wire is directly proportional to the length l between those two points,

Mathematically, $V \alpha l$

PROCEDURE

1. Set up the electrical circuit as shown in Fig. A 6.1.
2. Connect positive terminal of the battery to point A (zero length) of the potentiometer.
3. Connect negative end of the battery to the other end B (point) of the potentiometer wire through plug key and a rheostat.
4. Connect positive (red) lead of the multimeter used as voltmeter to point A and other end to a jockey J.

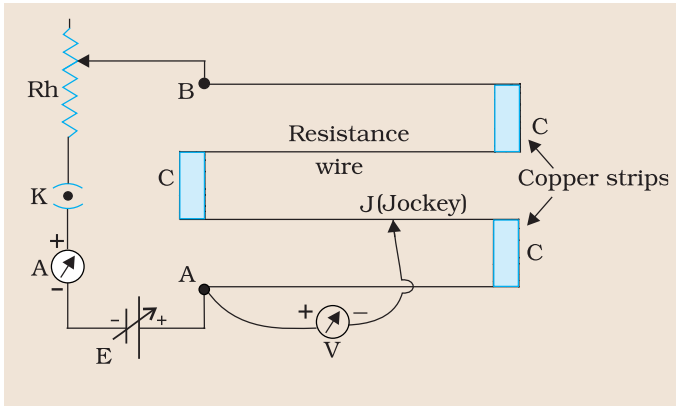

Fig. A 6.1: *Circuit to study variation in potential drop with length*

5. Now close the key K and press the jokey at point B. Adjust the rheostat to get maximum reading in multimeter.
6. When jokey is pressed at point A, you will get zero or minimum reading in the multimeter.
7. Now press the jokey say at 40 cm and note the corresponding reading of the multimeter.
8. Repeat your observations by pressing the jockey at various lengths like 80 cm, 120 cm etc., which may extend up to, say 400 cm of potentiometer wire. Record reading of the multimeter in each case as shown in Table A 6.1.

OBSERVATIONS

Range of the voltmeter (multimeter) = ...V

Least count of the voltmeter (multimeter) = ...V

Table A 6.1: Variation in potential drop with length

Sl. No.	Length of potentiometer wire over which potential drop is measured l (cm)	Voltmeter reading V (V)	$\phi = V/l$ (V cm^{-1})
1.			
2.			
3.			
4.			
		Mean	

CALCULATIONS

The ratio $\left(\frac{V}{l}\right) = \phi$ is calculated. It is the potential gradient of the wire. Its value is almost constant.

PLOTTING GRAPH

Plot a graph of V versus I, with V on y-axis and I on x-axis. Slope of the line gives ϕ.

The ratio $\left(\frac{V}{l}\right) = \phi$ is found to be constant. Its mean value is... V cm^{-1}.

The graph shows a linear relationship between V and l. The value of $\left(\frac{V}{l}\right) = \phi$ from the graph is ... V cm^{-1}.

10_XII_Activity_1_6 Folder.indd 178 05-10-2018 12:58:29

PRECAUTIONS

1. The current in the wire should remain constant throughout the experiment. To ensure this, current should be drawn intermittently for short duration of time. To ensure this, the battery should be fully charged.

SOURCES OF ERROR

1. The wire must have a uniform cross section along its entire length. If it is not so, $\frac{V}{I} = \phi$ will not be constant.
2. Emf of the battery should be constant throughout the experiment. Otherwise, $\frac{V}{I} = \phi$ will not be constant.

10_XII_Activity_1_6 Folder.indd 179 05-10-2018 12:58:30

ACTIVITY 7

AIM

To study the effect of intensity of light (by varying distance of the source) on a LDR (Light Dependent Resistor).

APPARATUS AND MATERIAL REQUIRED

LDR, torch, metre scale, multimeter and laboratory stand.

PRINCIPLE

Light dependent resistor or a photoresistor is a device that is sensitive to light. Its resistance varies according to the intensity of light incident on it. It is made from a semiconductor material with light resistors to have light sensitive properties, one such material is, cadmium sulphide. Snake-like coils are made of cadmium sulphide on thin metal films (Fig. A 7.1). LDR has a high resistance due to the fact that majority of electrons are locked into the crystal lattices and not free to move. As light falls on the lattice, some of the electrons get sufficient energy to break free the crystal lattice to conduct electricity. A typical LDR has resistance of 1 MΩ in total darkness and a few hundred ohm resistance in bright light.

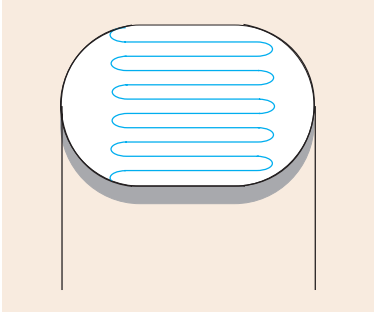

Fig. A 7.1: *A Light Dependent Resistance (LDR)*

PROCEDURE

1. Set up a torch on a fixed stand in vertical position facing LDR. Adjust LDR normally below the lamp at about 10cm (say).
2. Observe the reading of resistance using multimeter.
3. Changing the distance between torch or lamp and LDR by 15cm (say), repeat Step1. Record your observation and calculate resistance of LDR at different distances of the torch.

OBSERVATIONS AND CALCULATIONS

Table A 7.1 : Variation in resistance of LDR with distance

Sl. No.	Distance between torch and LDR d(m)	Resistance of LDR R(Ω)	d^2 (m^2)
1.			
2.			
3.			
4.			

RESULT

As distance increases, intensity of incident light decreases and resistance of LDR increases.

PRECAUTIONS

1. LDR is placed normally to the light source so that angle of incidence of light rays remain constant and normal throughout the experiment.
2. All the connections should be made tight.

SOURCES OF ERROR

Background illumination is a source of error in this activity.

11_XII_Activity 7-11 Folder.indd 181 04-10-2018 17:15:08

ACTIVITY 8

AIM

To identify a diode, a LED, a transistor, an IC, a resistor and a capacitor from a mixed collection of such items.

APPARATUS AND MATERIAL REQUIRED

Multimeter, a collection of diode, LED, transistor, IC, resistor and capacitor.

PRINCIPLE

1. A diode (p-n junction) is a two terminal device. It conducts when forward biased and does not conduct when reverse biased. The side having a silver band is n-side and the other side is p-side [Fig. 8.1a].
2. A LED (light emitting diode) is a p-n junction diode that emits light. It is also a two terminal device. It conducts when forward biased and does not conduct when reverse biased [Fig. 8.1b]. The long pin is connected from p-side and short pin from n-side.
3. A transistor is a three terminal semiconductor device. The terminals represent emitter (E), base (B) and collector (C) [Fig. 8.1c].
4. An IC (integrated circuit) is a multi-terminal device in the form of a chip [Fig. 8.1d].
5. A resistor is a two terminal device. It conducts equally in both directions [Fig. 8.1e].
6. A capacitor is a two terminal device. It stores some charge when dc voltage is applied [Fig. 8.1f].

PROCEDURE

1. A black rectangular shaped block having more than 3 legs may be IC.
2. A three terminal device: Connect central pin to red lead of the multimeter and any extreme pin to black lead of the multimeter.

Set the multimeter in diode mode (→|-). If it shows no reading, i.e., it shows 1, then it is a pnp transistor. If reading of ~0.4 – 0.8 (forwad voltage drop) is seen, it is npn transistor.

3. A two terminal device may be a resistor, a capacitor or a diode.
4. A two terminal device which conducts only in one direction is a pn junction diode. Set the multimeter in diode mode and connect the red lead to p-side of the diode and black lead to n-type of diode. It will show reading in range 0.4–0.8.
5. A two terminal device which conducts only in one direction with emission of light is LED.
6. Two terminal device which conducts in both directions is resistor. Read its resistance with the help of colour code and verify with the help of multimeter (using its resistance mode).
7. Two terminal device which gives reading initially and decays to zero is capacitor.
8. Results may be consolidated to draw the inferences.

OBSERVATION

Table: A 8.1 Checking for the number of terminals

Sl.No	No. of Terminals	Name of the Device
1.	Two	
2.	Three	
3.	More than three	

Table A 8.2 Checking for the state of conduction

Sl.No	State of Conduction	Device Code	Name of the Device
1.	Conducts in one direction only without any emission of light		
2.	Conducts in one direction only with emission of light		
3.	Three terminal device; conducts in one direction only between central terminal and either of the remaining two terminals		
4.	Conducts in both directions		
5.	Does not conduct, gives an initial deflection which decays to zero		

11_XII_Activity 7-11 Folder.indd 183 04-10-2018 17:15:08

RESULT

A diode, a LED, a transistor, an IC, a resistor and a capacitor are identified respectively from a mixed collection.

PRECAUTIONS

1. While obtaining resistance of any component, clean its leads properly.
2. While checking resistance of a component, avoid touching either of the metal ends of the multi-meter leads. Body resistance in parallel with component resistance can affect the resistance measurement.
3. Handle all the equipments very carefully.

Table A 8.3: Actual pictures of few electronic components along with their circuit symbols

S.No.	Electronic Components	Actual Picture	*Symbolic representation*
1.	Diode		
2.	LED		
3.	Transistor		
4.	IC		
5.	Resistor		
6.	Capacitor		

11_XII_Activity 7-11 Folder.indd 184 04-10-2018 17:15:09

ACTIVITY 9

AIM

(i) Check whether the diode is in working order.

(ii) Distinguish between npn and pnp transistor.

(iii) Identify base, emitter, and collector of a transistor.

MATERIAL REQUIRED

A digital multimeter, a diode and a transistor.

PROCEDURE

1. To check a diode connect the black lead to 'COM' jack of multimeter and red lead to 'V Ω mA' jack.

   (i) Set the selector knob of digital multimeter in the diode mode (→|). Connect the red lead (positive lead) of the multimeter to the anode of the diode and the black lead to the cathode of the diode (the cathode is always marked with a silver ring). The multimeter should show a reading in the range of ~0.4 – 0.8 forward voltage drop. If the reading is 0 then the diode is short circuited, it needs to be replaced. If the reading is 1 or over range, the diode is open circuited. It should be replaced.

   (ii) Reverse the diode connections with the multimeter (red lead to cathode, black lead to anode). The multimeter should show a reading of 1 or over range (indicating open circuit in reverse bias). If the multimeter reading is 0 then the diode is short circuited, it needs to be replaced.

2. (i) To distinguish between npn and pnp transistor set the selector knob of digital multimeter in diode mode. Connect the red lead of the multimeter to the central terminal of the

transistor and the black lead of the multimeter to any one of the extreme terminals of the transistor. If the multimeter displays a reading of ~0.4 – 0.8 (pn junction voltage drop), the junction is fine, and the central pin is p and outer terminal is n. If it shows any other reading then the junction is damaged. Check the voltage drop across the central terminal and the other outer terminal, if the reading is between ~0.4 – 0.8 the junction is fine and the central pin is p and the outer terminal is n. This implies that the transistor is an npn transistor.

(ii) Repeat the experiment with the black lead of the multimeter connected to the central pin and red lead connected to the outer terminal consecutively. If the readings for both the cases is in the range of ~0.4 – 0.8 then the transistor is a pnp transistor.

(iii) The central pin is the base and the outer ones will be the collector and an emitter.

3. (i) To identify base, emitter and collector of a transistor. It is not possible to distinguish between the emitter and collector using the diode range of the multimeter.

(ii) One can refer to the datasheet for the specific transistor. The manufacturer of the transistor gives the complete pin outs and the specifications of the transistor in its datasheet. One can also use the current gain (hfe) measurement setting of the multimeter to find the collector and emitter terminals. Set the multimeter in the hfe range and connect the transistor in the npn/pnp socket (depending on the types detected in the previous steps) with the assumed collector, base and emitter in their marked socket. If the meter shows a low reading (<10), reverse the position of the collector and emitter, and again check the hfe value. The hfe value should be above 100. If *hfe* value is greater than 100 it indicates that the collector, base, emitter terminals are connected in correct position and hence collector, emitter and base of the given transistor has been identified as per the multimeter transistor socket markings.

RESULT

1. A pn junction diode has been successfully tested and it is in working/not working order.
2. The transistor terminals were successfully identified as collector, base, emitter and distinguished as a npn or pnp device.

11_XII_Activity 7-11 Folder.indd 186 04-10-2018 17:15:09

ACTIVITY 10

AIM

To observe the refraction and lateral deviation of a beam of light incident obliquely on a glass slab.

APPARATUS AND MATERIAL REQUIRED

Drawing board, rectangular glass slab, white sheet of paper, adhesive tape (cellotape), drawing pins, a metre scale, alpins, protractor, pencil and eraser.

PROCEDURE

1. Fix a white sheet of paper on the drawing board with the help of cellotape or drawing pins.
2. Place the slab lengthwise symmetrically at the centre of the paper sheet and mark its boundary ABCD (Fig. A10.1) on the paper with a sharp pencil.
3. Draw a normal at a point F on the face AB. Draw a line EF, representing the incident ray, making an angle i (the angle of incidence) with the normal.
4. Fix two alpins P and Q with sharp tips, about 8 to 10 cm apart, vertically on the line EF.
5. Observe the images of the two pins through the opposite face of the glass slab. Fix two more alpins R and S about 8 to 10 cm apart, vertically on the white paper sheet carefully with their tips in line with the tips of the images of P and Q. Take care that the tips of all the alpins appear to be on a straight line.

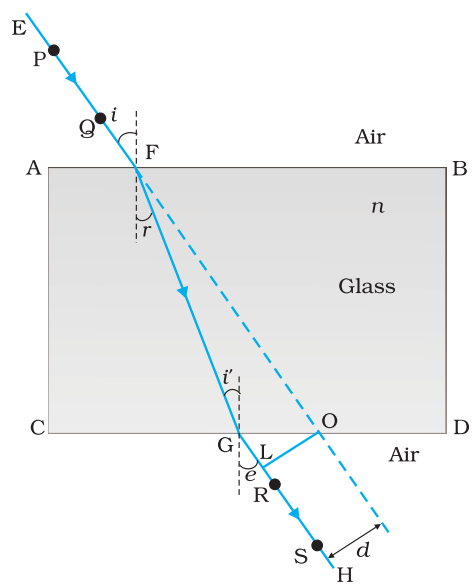

Fig. A 10.1: *Refraction through a rectangular glass slab*

6. Remove the glass slab and mark the pin prick positions of the alpins on the white paper sheet with a pencil. Draw a straight line GH, representing the emergent ray, passing through the points marked R and S, meeting the face CD at G.

7. Draw the line FG to represent the refracted ray. Draw a normal at the point G on the face CD making an angle of emergence e with the normal. Measure the angle of incidence i and angle of emergence e with a protractor. Write the values of these angles on the white paper sheet. Do you find some relation between $\angle i$ and $\angle e$?

8. Extrapolate EF forward to meet the face CD of the glass slab at O. Draw the perpendicular OL to the line GH.

9. Check if the emergent ray GH is parallel to the incident ray EF along the original direction. It is laterally deviated by a perpendicular distance OL. Measure the lateral deviation OL = d and also the thickness of the glass slab.

10. Repeat Steps 2 to 9 by changing the angle of incidence.

11. Repeat the Steps 2 to 10 by using glass slabs of different thicknesses. Measure the lateral deviation and the thickness of the glass slab each time. Also write the values of $\angle i$ and $\angle e$ on the white paper sheet each time.

12. Record observations in tabular form with proper units. What inference do you draw from your observations?

CONCLUSION

1. The ray of light emerging from a glass slab is parallel to the incident ray direction, but is laterally deviated.

2. The lateral deviation of the emergent ray with respect to the incident ray is directly proportional to the thickness of the glass slab

11_XII_Activity 7-11 Folder.indd 188 04-10-2018 17:15:09

ACTIVITY 11

AIM

To observe the polarisation of light using two polaroids.

APPARATUS AND MATERIAL REQUIRED

Two polaroid sheets, source of light/sunlight, card board, a pair of scissors, white paper and glue.

PROCEDURE

1. Hold one piece of polaroid with your hand and look through it at a bright object say a lighted bulb or a tubelight. Note the change in intensity of light of the bright object.

   Repeat the above with the other piece of polaroid.

2. Hold both the polaroids keeping them 10–12 cm apart. Now look through the two polaroids at the same bright object and note the intensity of light.

3. Slowly rotate one of the polaroids keeping the other polaroid fixed. Note the change in intensity of bright object as you rotate the Polaroid. Find the two alignment of polaroids when the light is maximum and when it is minimum.

CONCLUSION

The plane of polarisation of the polaroids are parallel when the observed intensity of light is maximum and it is perpendicular when intensity of light is minimum.

ACTIVITY 12

AIM

To observe the diffraction of light due to a thin slit.

APPARATUS AND MATERIAL REQUIRED

Two razor blades, one adhesive tape/cellotape source of light (electric bulb/laser torch), a piece of black paper and a glass plate (10 cm×10 cm).

PROCEDURE

1. Make a fine, single slit using two razor blades. For this purpose, take a glass plate and fix black paper on top of it. Cut out a narrow slit in the central part of the black paper. Place two razor blades side by side, quite close to each other over this slit as shown in Fig. A 12.1

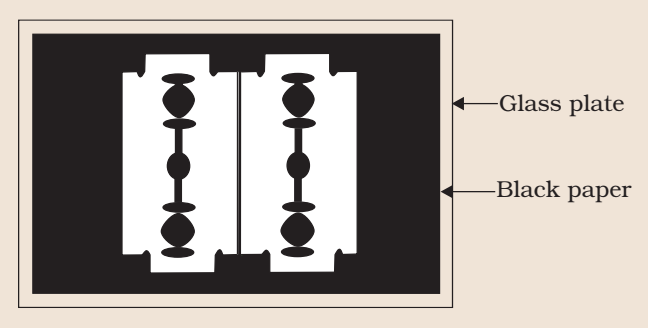

Fig. A 12.1: *A fine slit made by using two razor blades, one glass slide and a piece of black paper*

2. Place a glowing clear electric lamp (say 100 W bulb) preferably with a straight filament (or a laser torch) at about 4 to 8 m behind the fine slit between the two sharp edges of the razor blades. Observe the lamp through the slit. What do you find?
3. Alternatively, place the slit about 50 cm from a wall and place the source of light at a distance of about 15–20 cm behind the slit. Observe light falling on the wall with slight adjustment of the width of the slit and the parallelism of the edges, the pattern will be seen with its bright and dark bands. By this way you can observe single slit diffraction pattern.
4. Repeat the observations of steps 2 and 3 with a laser torch. Note the changes you observe.

CONCLUSION

Light waves incident on very fine apertures (openings) bend around its edges/corners and exhibit phenomenon of diffraction.

ACTIVITY 13

AIM

To study the nature and size of the image formed by (i) a convex lens (ii) a concave mirror on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror).

(i) To study nature and the size of the image formed by a convex lens (for different distances of the candle from the lens).

APPARATUS AND MATERIAL REQUIRED

Improvised optical bench setup, a candle, match box, a small candle stand, a convex lens of small focal length and a metre scale.

PROCEDURE

1. Obtain an approximate value of the focal length of the convex lens by focusing the image of a distant object. It can be found by obtaining a sharp image of Sun or a tree on a plain wall, on the other side of the lens and measuring the distance between the lens and the wall with a scale. This distance gives approximate value of the focal length, f of the convex lens.

Note: Do not look at the Sun through the lens to see its image as it will hurt your eyes.

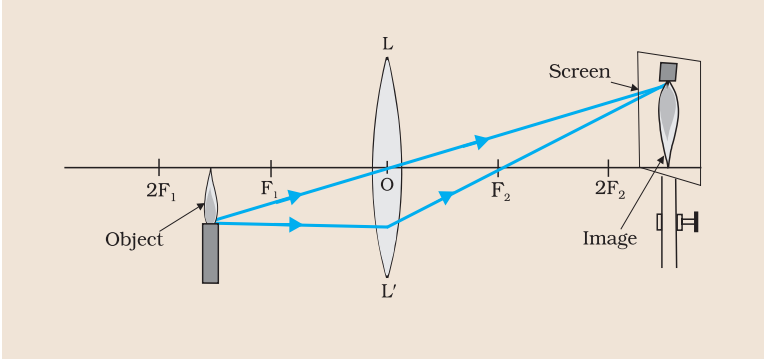

Fig. A 13.1: *Real image of a lighted candle formed by a thin convex lens*

2. Fix lens LL' in a lens holder with stand and place it approximately in the middle of the optical bench such that its principal axis is horizontal and parallel to the optical bench. In this position the lens would lie in a plane perpendicular to the optical bench.
3. Place a vertically mounted screen on the right hand side of the lens. Adjust its height such that most of its portion lies above the principal axis of the lens.
4. Mount a lighted candle vertically on a small candle stand. Place this candle stand on the left hand side of the lens. Adjust the upright such that the tip of the lighted candle lies on the principal axis of the lens. In this situation, the height of the tip of the flame of lighted candle will be at the same height as the optical centre of the lens.
5. Shift the candle stand (from left side of the lens) to a point slightly away from $2F_1$ (i.e., to a distance slightly more than $2f$ from the lens, where f is the approximate focal length of the lens as determined in Step 1). The image of candle will be formed at a position closer to the second principal focus F_2 on the right hand side of the lens.
6. Shift the position of the screen towards the lens till you observe an inverted image of the candle flame on it.
7. Make final adjustment to get a sharp image of the lighted candle lamp on the screen. Note the nature of the image.
8. Compare the height of the flame of the lighted candle with the size of its image for different positions of the object. Also note whether the image is erect or inverted.

CONCLUSION

1. As the object moves towards the focus of the lens the size of the image increases and it moves away from the focus. In all these positions image is real and inverted and is formed on the other side of the lens.
2. When the object is at distance less than the focal length, the image formed is virtual, enlarged and erect. It is formed on the same side of the lens as that of the object.

PRECAUTIONS

1. This activity should preferably be performed inside a dark room otherwise the image may not be clearly visible.

12_XII_Activity_12_14 Folder.indd 192 05-10-2018 14:16:15

2. While estimating the rough value of focal length *f* of the lens by focusing the Sun, do not look at the image directly as it may hurt your eyes.
3. The uprights supporting the optical elements should be rigid and mounted vertically.

AIM

(ii) To study the nature and size of the image formed by a concave mirror on a screen by using a candle and a screen (for different distances of the candle from the concave mirror).

APPARATUS AND MATERIAL REQUIRED

Improvised optical banch setup, candle, match box, a small candle stand, concave mirror of nearly 25 cm focal length and a metre scale.

PROCEDURE

1. Obtain an approximate value of the focal length of the concave mirror by focusing the image of a distant object. It can be found by obtaining a sharp image of the sun or a tree on a plane wall, or on a sheet of paper and measuring the distance between the mirror and the image with a scale. This distance is an approximate value of the focal length, F of the concave mirror. Twice of this focal length is an approximate value of the radius of curvature of the mirror.
2. Set the optical bench properly.
3. Fix the concave mirror on the mirror holder and place it near one end of the meter scale.
4. Mount a lighted candle vertically in such a way that tip of the bright flame reaches up to the level of pole of the mirror. Place the candle arrangement near the mirror.
5. Mount the screen on upright.
6. Move the candle slowly away from the mirror till the image of its flame is seen on the screen. Adjust the position of the screen till the image becomes distinctly visible.
7. Compare the size of the candle flame with the size of the image. Also note whether the image is erect or inverted.

12_XII_Activity_12_14 Folder.indd 193 05-10-2018 14:16:15

8. Repeat the above steps for different positions of candle with respect to the mirror. Compare the size of flame and its image and also its nature in each case.

CONCLUSION

Observation on the nature, size and position of image shows that:

1. The image moves away from the focus as the object moves towards the focus.
2. The size of the image increases as it moves away from the mirror.
3. If the object is placed between infinity and F the image formed by a concave mirror is real and inverted.
4. If the object is placed between F and pole, the image is formed behind the mirror and it is virtual, erect and enlarged.

PRECAUTIONS

1. This experiment should preferably be performed inside a dark room, otherwise the images may not be clearly visible.
2. While estimating the rough value of focal length f of the mirror by focusing the sun, do not look at the sun through the mirror as it may hurt your eyes.
3. The stands for the mirror, screen and candle should be rigid and mounted vertically.

12_XII_Activity_12_14 Folder.indd 194 05-10-2018 14:16:15

ACTIVITY 14

AIM

To determine the focal length of two lenses in contact.

APPARATUS AND MATERIAL REQUIRED

Two convex lenses of known powers, optical bench with uprights and screen, a source of light providing a parallel beam of light (a collimator).

PROCEDURE

1. Find out the rough focal length of individual lenses. Assemble the optical bench following the steps suggested in Appendix-1.
2. Fix one of the two lenses L_1 (say) in the lens holder.
3. Place the screen, fixed in the upright, on one side of the optical bench.

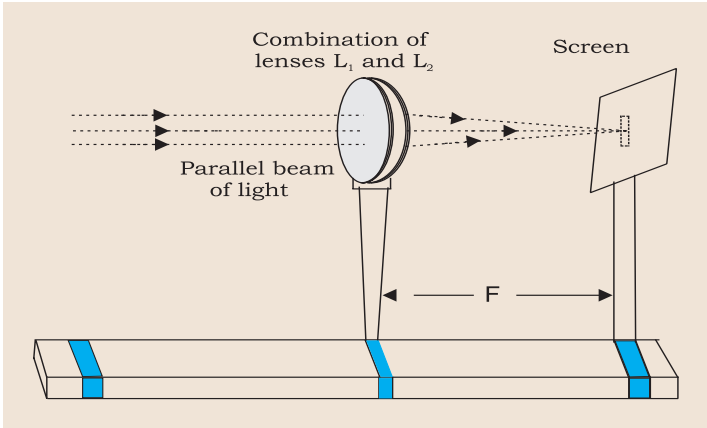

Fig. A 14.1 (a): *Focal length of combination of lenses*

4. Direct a parallel or nearly parallel light on the lens from other side. A parallel beam of light could be obtained by using a collimator or a torch light or a beam of sunlight reflected from a plane mirror.
5. Move the screen forward or backward until a sharp bright spot is observed on the screen.
6. Measure the distance between the lens and the screen which is the focal length f_1.

7. Repeat Steps 2 to 6 for the other lens L_2 and obtain its focal length f_2.
8. Mount both the lenses L_1 and L_2 together in the same lens holder without any gap between them. Repeat Steps 2 to 6 and obtain focal length F of the lens combination.
9. Compute the focal length of the combination of lenses using the formula given below,

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}$$

10. Compare the focal length of the combination of the lenses obtained experimentally with that of the computed focal length F.

CONCLUSION

Measured value of focal length of lens combination =....cm
Difference between measured value of focal length and the calculated focal length =....cm
The difference between the two could be due to experimental error.

12_XII_Activity_12_14 Folder.indd 196 05-10-2018 14:16:15

APPENDIX – 1

OPTICAL BENCH ASSEMBLING

1. Optical bench provided in the kit comprises of:

   (i) Four pieces of 50cm scales

   (ii) Interlocking pins – 4

   (iii) Strips for joining scales – 4

   (iv) Sliding bases for uprights – 4

   (v) Sliding upright holder – 4

   (vi) Mirror / Lens holder – 2

   (vii) Screen (12 cm × 12 cm) – 1

   (viii) Object and image pencils – 2

   (ix) Spherical mirror / lenses

2. For setting up the optical bench you will also require a spirit level for checking its level.
3. Join two halves of 1 metre scales along their length using joining strips.
4. Ensure that the 50 cm mark of the two scales are at the middle. Similarly join the other two halves of one metre scale.
5. Place these two joined scales side by side and fasten their ends using two locking pins on both the ends.
6. Check the level of the two scale assembly with spirit level if required relocate the assembly or level it with the pieces of paper/cardboard.
7. This scale assembly is to be used as optical bench.
8. Place one sliding base on the optical bench (scale assembly) such that slots provided at its bottom fits into the optical bench. Move the sliding base along the entire length of the bench to ensure smooth movement. Repeat for all other sliding bases.
9. Slide upright holders into sliding bases. The upright holder with a horizontal groove is to be used for holding screen.
   This completes the assembling part of optical bench.

12_XII_Activity_12_14 Folder.indd 197 05-10-2018 14:16:15

Notes

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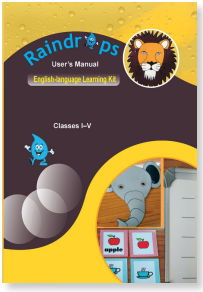

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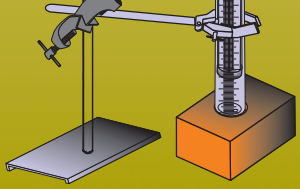

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